Bode 100

User Manual

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Using This Manual

This User Manual provides detailed information on how to use all functions of the *Bode 100* vector network analyzer properly and efficiently. The Bode 100 User Manual is intended for all users of the *Bode 100*, providing instructions on the operation, usage, and measurement procedures.

Any user of the *Bode 100* should have fundamental working knowledge of basic electronics, general measurement techniques, and the use of computer-based applications running under a Windows® environment.

Conventions and Symbols Used

In this manual, the following symbol indicates paragraphs with special safety relevant meaning:

Symbol	Description
	Equipment damage or loss of data possible

Related Documents

The following documents complete the information covered in the Bode 100 User Manual:

Title	Description
Automation Interface Object Hierarchy and Automation Interface Reference (available in the *Automation* subdirectory of the *Bode Analyzer Suite* directory)	Provide detailed information on the *Bode Analyzer Automation Interface*.

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1 Introduction

1.1 Overview

The *Bode 100* is a multifunctional test & measurement instrument designed for professionals such as scientists, engineers and teachers engaged in the field of electronics. Its concept – universal hardware controlled by the *Bode Analyzer Suite* software running on a computer – makes the *Bode 100* an efficient and flexible solution for a wide spectrum of applications including:

- **Gain/Phase** measurements
  The *Bode 100* measures the gain and phase of passive and active electronic circuits as well as complex electronic systems such as closed-loop control systems, video systems and RF equipment.
- **Impedance/Reflection** measurements
  The *Bode 100* measures the impedance, admittance and reflection coefficient of passive and active electronic circuits. An internal bridge allows performing measurements by just connecting the device under test (DUT) to the *Bode 100* source.
- **Frequency Sweep** measurements
  In addition to single frequency measurements, the *Bode 100* performs measurements in the **Frequency Sweep** mode.
  In this measurement mode, the *Bode 100* is capable of measuring the complex gain, reflection coefficient and impedance of the DUT. The results are displayed as a function of the frequency in various display formats such as group delay curves or Smith charts.
- **Frequency Sweep (External Coupler)** measurements
  In this measurement mode you can measure the complex impedance, admittance and reflection coefficient of the DUT by using an external directional coupler or other external measurement bridge. Typical application examples include measurements of broadcast antennas and impedance measurements with signal levels above 20 mW.

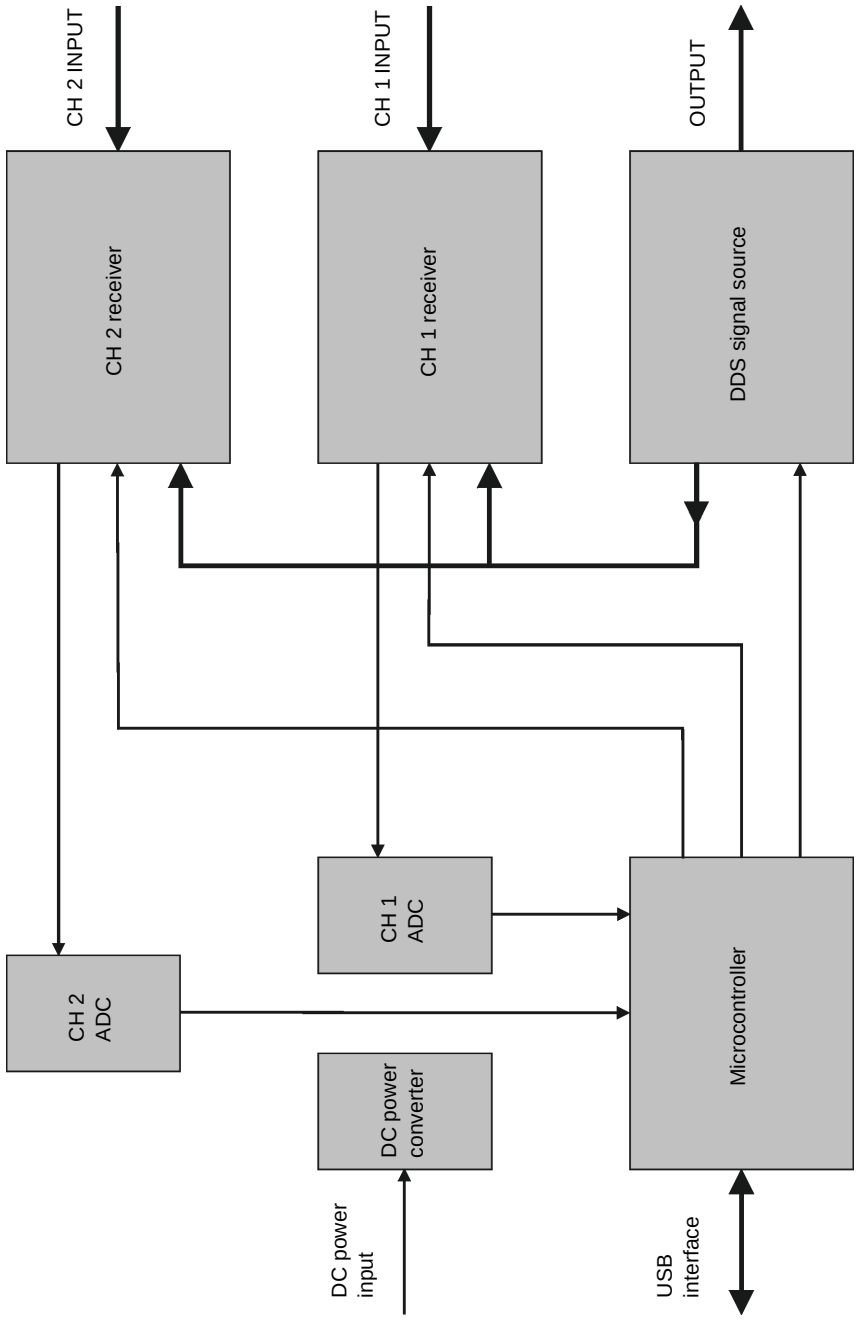
The measurement results are available on your computer for processing and/or documentation.

The *Bode 100* includes a DDS (direct digital synthesis) signal source with adjustable level and frequency for excitation of the DUT, two receivers processing the DUT's response and a microcontroller. A DC power converter generates voltages for powering the circuitry involved. For the basic block diagram of the *Bode 100*, see Figure 1-1: "Block diagram" on page 10.

The *Bode Analyzer Suite* runs on a computer connected to the *Bode 100* through USB interface.

1.2 Block Diagram

Figure 1-1:
Block diagram



1.3 Connectors

Caution: To avoid damage of the *Bode 100*, check 12.3 "Absolute Maximum Ratings" on page 136 for maximum input signals at the CH 1 INPUT and CH 2 INPUT connectors and maximum reverse power at the OUTPUT connector.

The *Bode 100* provides the following connectors:

- OUTPUT (signal source output) on the front panel
- CH 1 INPUT (channel 1 input) on the front panel
- CH 2 INPUT (channel 2 input) on the front panel
- DC power input on the rear panel
- USB connector on the rear panel

Figure 1-2:
Bode 100 front view

Figure 1-3:
Bode 100 rear view

1.4 Standard Compliance

The *Bode 100* complies with the following standards:

Table 1-1:
Standard compliance

Standard	Description
IEC 61326: Class B equipment Performance criterion B	EMC requirements
Universal Serial Bus (USB) Specification, Revision 1.1 and Revision 2.0	USB interface

1.5 Normative Conformity

The *Bode 100* conforms to the following normative documents of the EU:

Table 1-2:
Conformity documents

Document	Description
73/23/EWG	Concerning electrical devices for use of certain voltage limits with changes due to the CE designation standard 93/68/EWG
89/336/EWG	About electromagnetic compatibility changed by the standard of the Council from 1991-04-29 (91/263/EWG), the standard of the Council from 1992-04-28 (92/31/EWG), and the standard of the Council from 1993-07-22 (93/68/EWG)

1.6 Test Compliance

The *Bode 100* passed the tests according to the EN/IEC 61010-1, IEC 61326.

1.7 Delivery

Bode 100 multifunctional vector network analyzer	*Bode 100* CD-ROM	Wide-range AC power supply including mains input plugs for different national standards
Test objects on a PCB: quartz filter, IF filter	USB cable	4 × BNC 50 Ω cable (m–m)
BNC straight adapter (f–f)	BNC T adapter (f–f–f)	BNC short circuit (m)
BNC 50 Ω load (m)	Bode 100 User Manual	The delivered items may differ slightly from the picture.

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2 Getting Started

Caution: Before installing the *Bode 100*, check the environmental and power requirements (see 12 "Technical Data" on page 135).

2.1 Installing the *Bode Analyzer Suite*

Caution: Install the *Bode Analyzer Suite* from the delivered CD-ROM before connecting the *Bode 100* to the USB connector of your computer.

The *Bode Analyzer Suite* on the delivered CD-ROM controls the operation of the *Bode 100*. Install the *Bode Analyzer Suite* first, before you connect the *Bode 100* to the computer. Put the *Bode 100* CD-ROM in the CD-ROM drive and follow the instructions on the screen. Select the 32-bit or 64-bit installation according to your computer's hardware. For installation support, visit the OMICRON Lab Web site www.omicron-lab.com or contact your nearest support center (see "Contact Information / Technical Support" on page 139).

2.2 Powering the *Bode 100*

Caution: Before powering the *Bode 100* using a DC power supply different from the one delivered with the *Bode 100*, check the polarity of its output voltage (see 12.2 "Power Requirements" on page 136).

The *Bode 100* is powered with an external wide-range AC power adapter. Before powering the *Bode 100*, select the adapter's mains input plug fitting your power outlet. Plug the adapter's DC output connector into the *Bode 100* DC power input on the rear panel and the mains input plug into the power outlet. Alternatively, you can power the *Bode 100* with any DC power supply meeting the power requirements specified on page 136.

2.3 Connecting the *Bode 100* to the Computer

The *Bode 100* communicates with the computer through USB interface (see 12.4 "Computer Requirements" on page 137). Connect the *Bode 100* USB connector on the rear panel to the USB connector of your computer using the USB cable delivered with your *Bode 100*.

2.4 How to Proceed

Now, you are ready to work with your *Bode 100*. You can proceed with Section 3 "Gain/Phase Mode" to make your first measurement with the *Bode 100*, and then go through the Bode 100 User Manual to learn the capabilities of your *Bode 100* by doing practical examples. For the *Bode Analyzer Suite* basics, see Section 8 "Common Functions".

3 Gain/Phase Mode

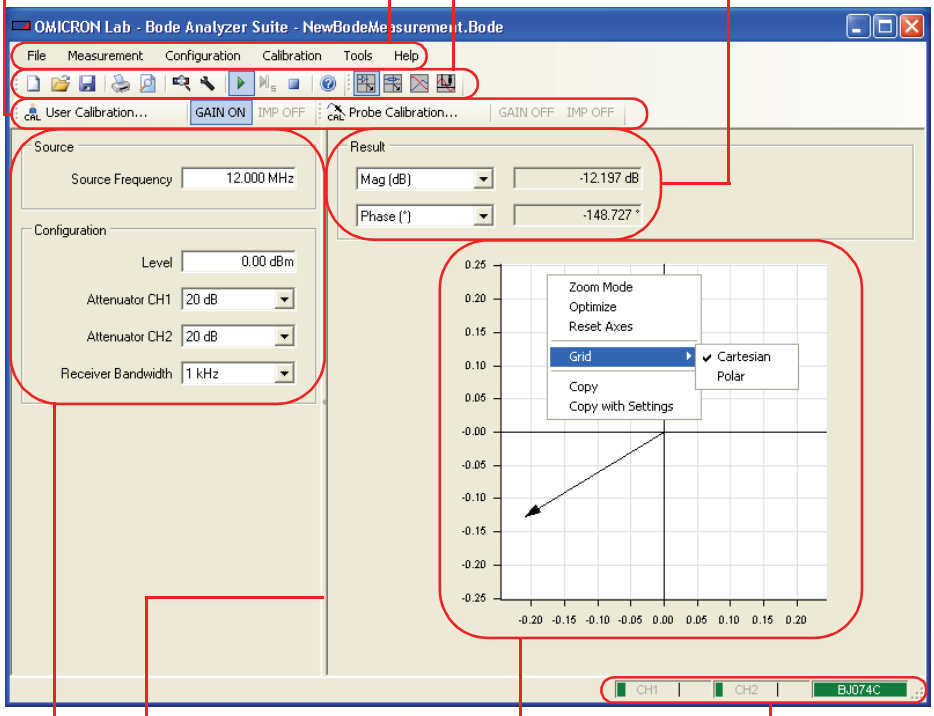
Figure 3-1: **Gain/Phase** mode window

Menu bar
Allows access to all *Bode 100* functions. See Table 8-1: "Menus and commands" on page 96.

Toolbar
Contains shortcuts to the most important *Bode 100* functions.
See Figure 8-1: "Toolbar" on page 95.

Calibration toolbar
Choose the calibration mode.
Switch the calibration on and off.
See Figure 8-2: "Calibration toolbar" on page 95.

Results
Select the result format and get result values.
See Figure 3-3: "Gain/Phase mode results" on page 18.



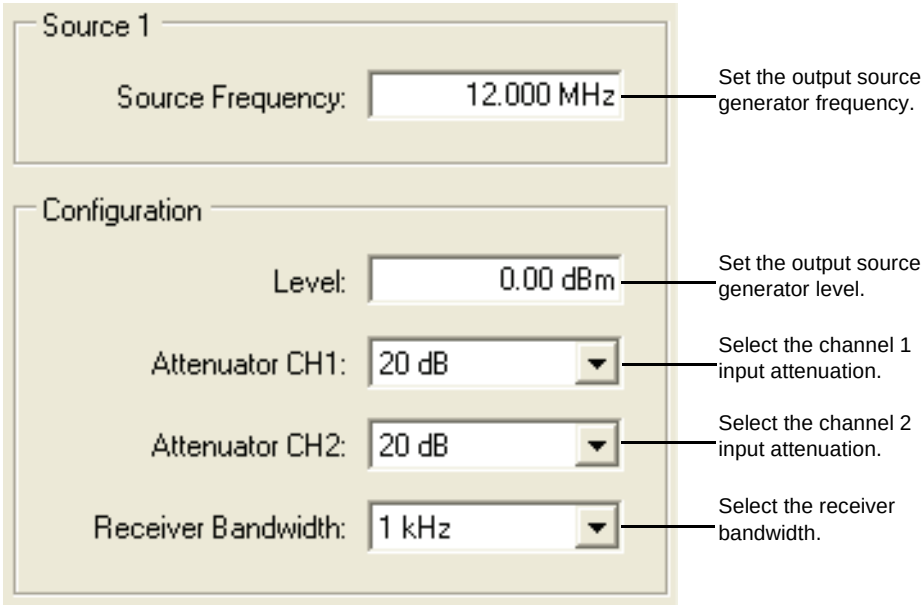
Split bar
Drag the split bar to resize the panes.

Configuration and measurement setup
See Figure 3-2: "Configuration and measurement setup" on page 18.

Overload and connection indicators
See Figure 3-5: "Overload and connection indicators" on page 19.

Graphical display of measurement results
Use the shortcut menu to optimize the display.
See Figure 3-4: "Graphical display of measurement results" on page 19.

Figure 3-2:
Configuration and measurement setup



Hint: A higher receiver bandwidth allows faster measurements, a lower receiver bandwidth increases the measurement accuracy.

Figure 3-3:
Gain/Phase mode results

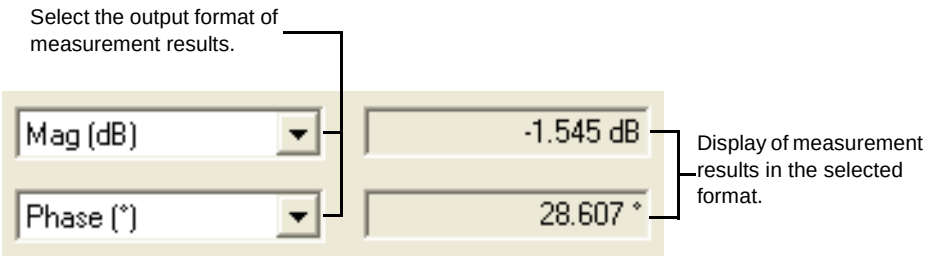
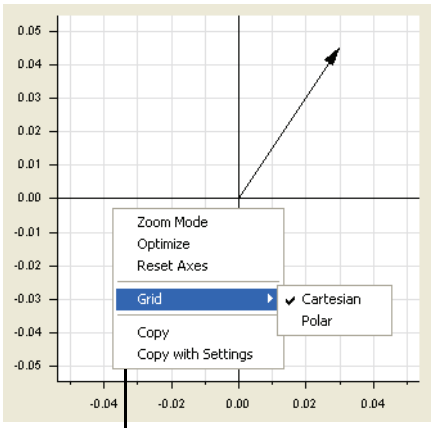


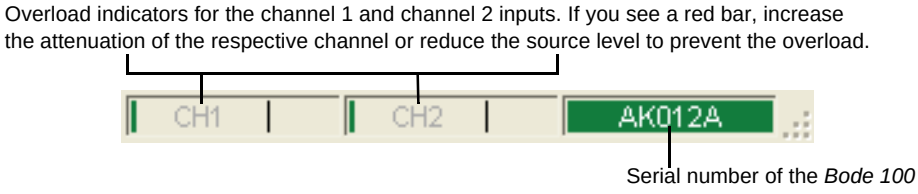
Figure 3-4:
Graphical display of measurement results



Right-click in the diagram to open the shortcut menu.
Use the shortcut menu to optimize the diagram, select the grid and zoom in the diagram. After having zoomed in, click **Optimize** to get back to an optimized diagram.

Hint: Using the **Copy** and **Copy with Settings** functions you can easily export your diagram into other Windows® applications. For more information, see 9.1 "Advanced Display Options" on page 101.

Figure 3-5:
Overload and connection indicators


Overload indicators for the channel 1 and channel 2 inputs. If you see a red bar, increase the attenuation of the respective channel or reduce the source level to prevent the overload.
CH1
CH2
AK012A
Serial number of the *Bode 100*

Hint: If the serial number field in the status bar displays **No Device** on red background, check whether the *Bode 100* is powered and connected to your computer, and then click the **Search and Reconnect Device** toolbar button to reconnect the *Bode 100*.

3.1 Basics

The gain and phase of the DUT is calculated from the measurement data obtained using the reference channel 1 and the measurement channel 2. You can connect the signal source to the reference channel internally or externally as described in 3.2 "Choosing the Reference Connection" on page 22.

The basic definitions and formulas related to the gain/phase measurements are summarized below:

$$|\underline{H}(f)| = \mathrm{abs}\{\underline{H}(f)\} \quad \text{(Eq. 3-1)}$$

$$\phi(f) = \arg\{\underline{H}(f)\} \quad \text{(Eq. 3-2)}$$

$$T_g(f) = -\frac{1}{2\pi} \bullet \frac{\mathrm{d}}{\mathrm{d}f}\phi(f) = -\frac{\mathrm{d}}{\mathrm{d}\omega}\phi(\omega) \quad \text{(Eq. 3-3)}$$

where
$\underline{H}(f)$ …displayed gain/phase function
$|\underline{H}(f)|$ …magnitude of $\underline{H}(f)$
$\phi(f)$ …phase of $\underline{H}(f)$
$T_g(f)$ …group delay of $\underline{H}(f)$

$$\underline{S}_{ji}(f) = 2 \bullet \frac{\underline{V}_{OUT}}{\underline{V}_0}, i \neq j \quad \text{(Eq. 3-4)}$$

$$\underline{H}_T(f) = \frac{\underline{V}_{OUT}}{\underline{V}_{IN}} \quad \text{(Eq. 3-5)}$$

where
$\underline{S}_{ji}(f)$ …S parameter from port *i* to port *j* $(i \neq j)$ of the DUT
$\underline{H}_T(f)$ …transfer function of a two-port device, $\underline{H}_T(f)$ depends on the load of the port where $\underline{V}_{OUT}$ is measured
$\underline{V}_{OUT}$ …voltage at the DUT's output
$\underline{V}_0$ …open-circuit voltage of the source
$\underline{V}_{IN}$ …voltage at the DUT's input
$\underline{V}_{CH1}$ …voltage at the channel 1 input
$\underline{V}_{CH2}$ …voltage at the channel 2 input
$\underline{Z}_{IN}$ …input impedance of the DUT
R_S …50 Ω source resistance

Assumptions for measuring $\underline{S}_{ji}(f)$:

- The source with resistance R_S = 50 Ω is connected to port *i.*
- 50 Ω load (receiver resistance) at port *j* measuring $\underline{V}_{OUT}$, any other ports of the DUT are terminated with 50 Ω.
- Connections are made with 50 Ω cables.

3.1.1 Internal Reference Connection

The basic formulas for the internal reference connection are summarized below.

Note: In the internal reference connection mode of the *Bode 100*, the reference voltage for the gain/phase measurement is always $\underline{V}_0/2$.

Table 3-1: Formulas for Internal Reference Connection

Channel 2 Input Resistance	
50 Ω	**High Impedance**
$\underline{V}_{CH1} = \frac{\underline{V}_0}{2}$ (Eq. 3-6)	$\underline{V}_{CH1} = \frac{\underline{V}_0}{2}$ (Eq. 3-7)
$\underline{V}_{CH2} = \underline{V}_{OUT}$ (Eq. 3-8)	$\underline{V}_{CH2} = \underline{V}_{OUT}$ (Eq. 3-9) $\underline{V}_{IN} = \underline{V}_0 \bullet \frac{\underline{Z}_{IN}}{(\underline{Z}_{IN} + R_S)}$ (Eq. 3-10)
$\underline{H}(f) = \frac{\underline{V}_{CH2}}{\underline{V}_{CH1}} = 2 \bullet \frac{\underline{V}_{OUT}}{\underline{V}_0}$ $= S_{ji}(f)$ of the DUT (Eq. 3-11)	$\underline{H}(f) = \frac{\underline{V}_{CH2}}{\underline{V}_{CH1}} = 2 \bullet \frac{\underline{V}_{OUT}}{\underline{V}_0}$ $= 2 \bullet \frac{\underline{V}_{OUT}}{\underline{V}_{IN}} \bullet \frac{\underline{Z}_{IN}}{(\underline{Z}_{IN} + R_S)}$ (Eq. 3-12) $\underline{H}(f) = 2 \bullet \underline{H}_T(f) \bullet \frac{\underline{Z}_{IN}}{(\underline{Z}_{IN} + R_S)}$ (Eq. 3-13)
If you make a through connection from the source to CH 2: 0 dB gain will be displayed since $\underline{V}_{CH2} = \underline{V}_0/2$	If you make a through connection from the source to CH 2: +6 dB gain will be displayed since $\underline{V}_{CH2} = \underline{V}_0$

3.1.2 External Reference Connection

Independent of the selected input impedance at the channel 1and channel 2 inputs, the following formulas apply:

$$\underline{V}_{CH1} = \underline{V}_{IN} \quad \text{(Eq. 3-14)}$$

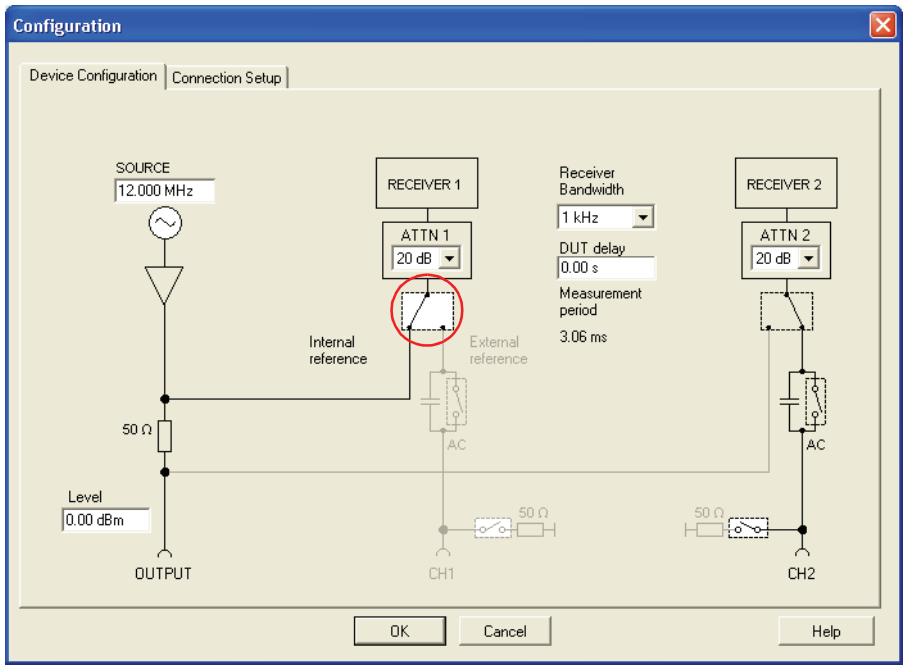
$$\underline{V}_{CH2} = \underline{V}_{OUT} \quad \text{(Eq. 3-15)}$$

$$\underline{H}(f) = \underline{H}_T(f) = \frac{\underline{V}_{CH2}}{\underline{V}_{CH1}} = \frac{\underline{V}_{OUT}}{\underline{V}_{IN}} \quad \text{(Eq. 3-16)}$$

3.2 Choosing the Reference Connection

Open the **Configuration** window by clicking **Device Configuration** on the **Configuration** menu or the **Device Configuration** toolbar button (see 3.3 "Example: Gain/Phase Measurement" on page 24). By default, the **Device Configuration** tab is selected.

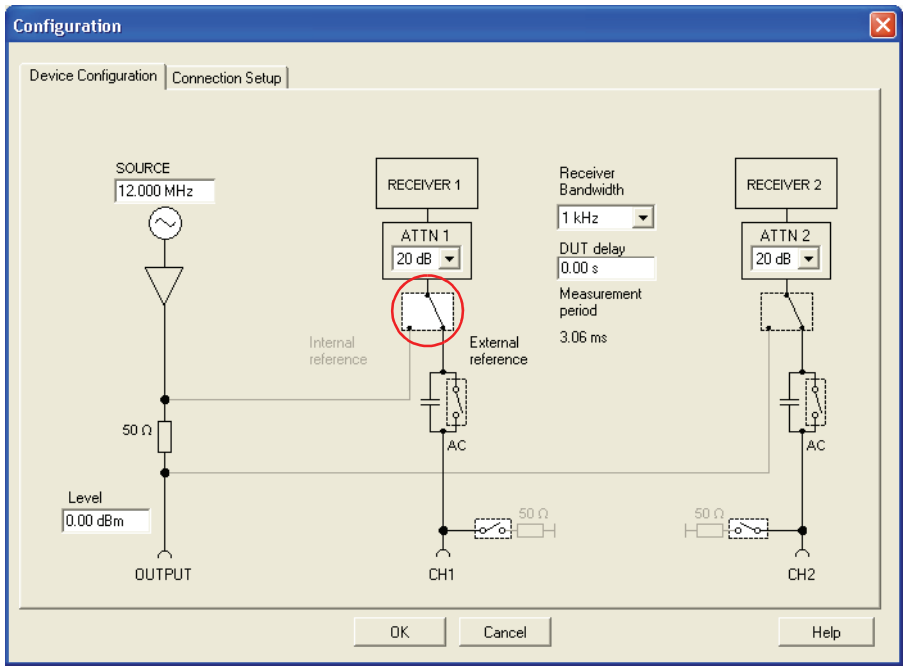
To connect the reference internally, set the marked configuration field as shown below.



Note: The source signal is internally connected to the channel 1 input in front of the 50 Ω source resistor (channel 1 voltage $\underline{V}_{CH1} = \underline{V}_0/2$ as defined in 3.1 "Basics" on page 20).

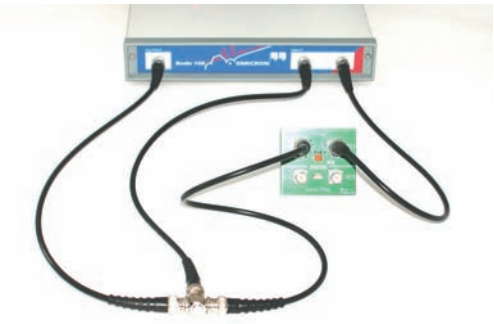
To connect the reference externally:

1. Set the marked configuration field as shown in the following figure.



Note: The source signal is externally connected to the channel 1 input behind the 50 Ω source resistor (channel 1 voltage $\underline{V}_{CH1} = \underline{V}_{IN}$ as defined in 3.1 "Basics" on page 20).

2. Connect the reference point of the DUT to the CH 1 INPUT connector using a cable.



3.3 Example: Gain/Phase Measurement

Expected example duration: 20 minutes.

In this example you will learn step by step how to use the **Gain/Phase** mode of the *Bode 100*.

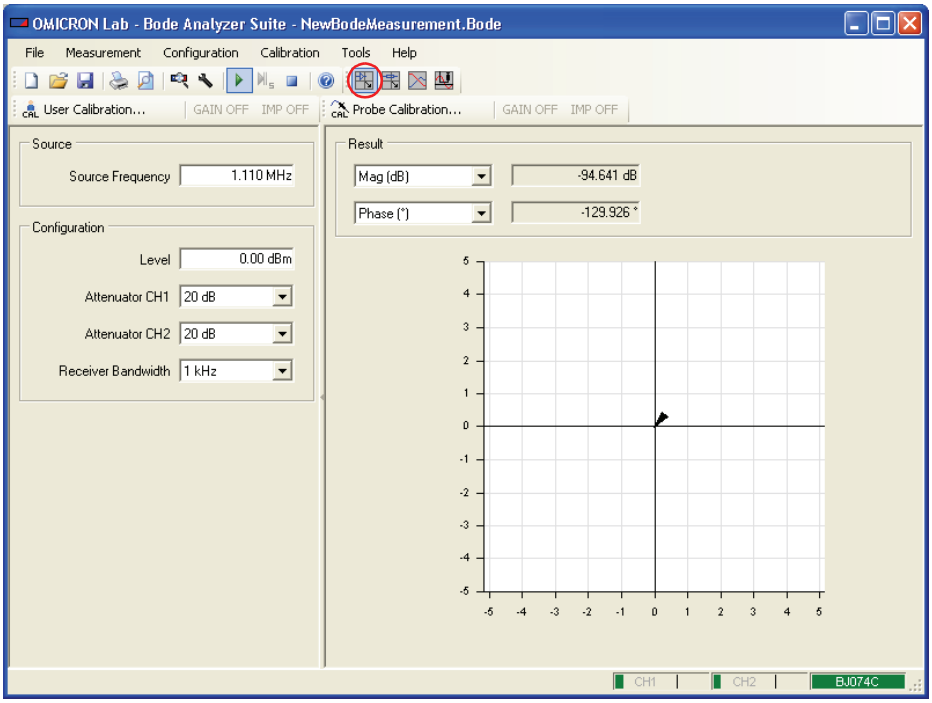
How to:

- Measure the gain and phase of a DUT with sinusoidal signal at a frequency
- Set the bandwidth, attenuators and amplitudes of the *Bode 100*
- Optimize the diagram
- Compensate the connection cables in the **Gain/Phase** mode

Question: What is the magnitude in dB of the delivered IF filter at 10.7 MHz? These types of 10.7 MHz filters are used in FM radios.

To find out the answer, proceed as follows:

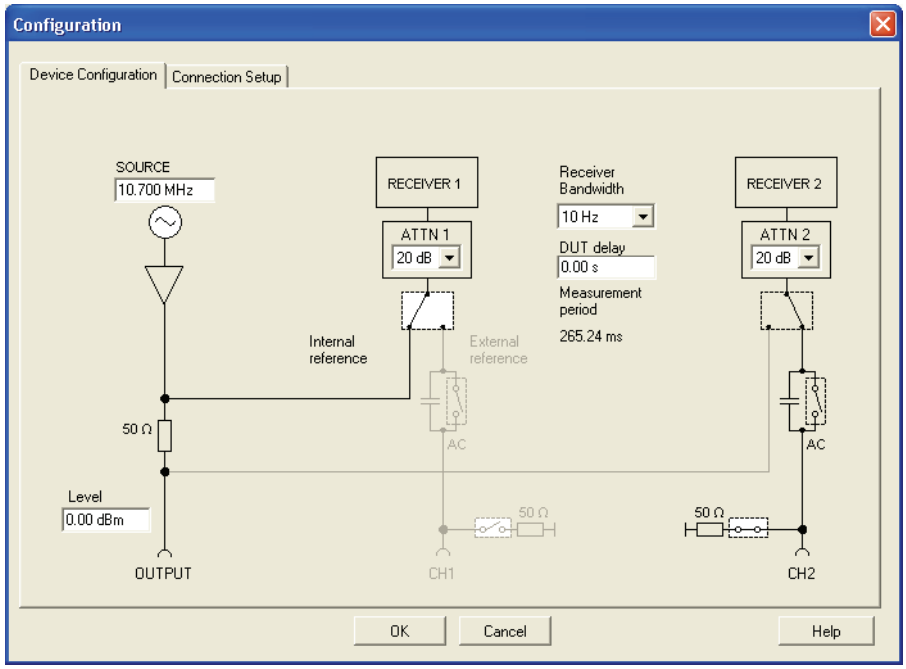
1. Connect the *Bode 100* and start the *Bode Analyzer Suite*.
2. Click the **Gain/Phase** toolbar button .



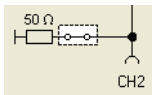
Hint: If you see the *Bode 100* serial number in the status bar on the lower right side of the window then the *Bode Analyzer Suite* communicates with the *Bode 100*. Otherwise check whether your *Bode 100* is connected and powered properly, and then click the **Search and Reconnect Device** toolbar button .

3. Click the **Device Configuration** toolbar button to configure the **Gain/Phase** mode.

4. In the **Configuration** window, set:



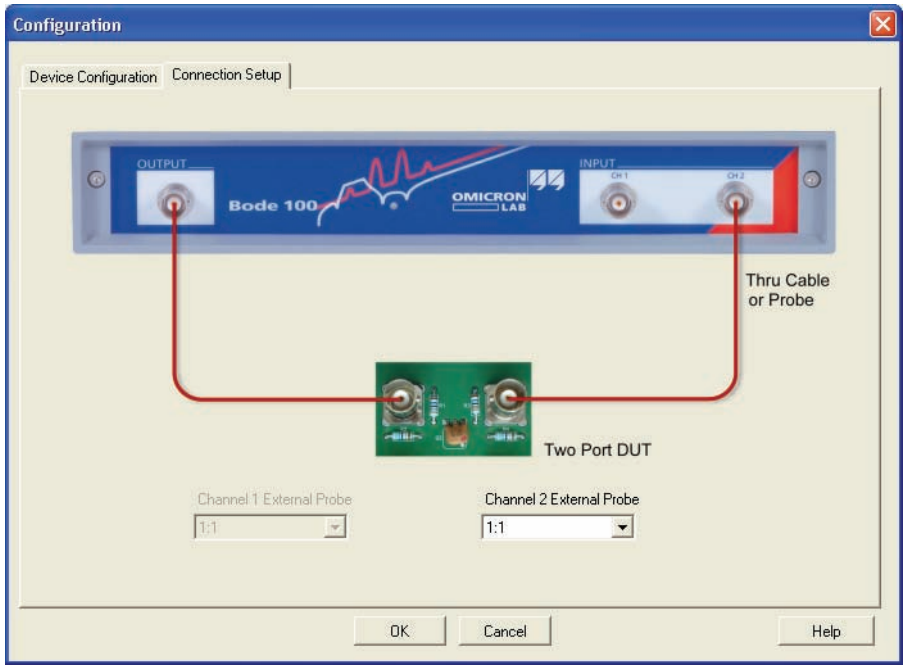
- CH2: 50 Ω ON (click the switch as shown)



- SOURCE: 10.7 MHz
- Receiver bandwidth: 10 Hz
- ATTN 1 (channel 1 input attenuator): 20 dB
- ATTN 2 (channel 2 input attenuator): 20 dB
- The switch (before ATTN1) to the internal source as reference
- Level: 0 dBm

Hint: Setting the receiver bandwidth to 10 Hz makes the readout more stable but also makes the measurement slower.

5. Click the **Connection Setup** tab.



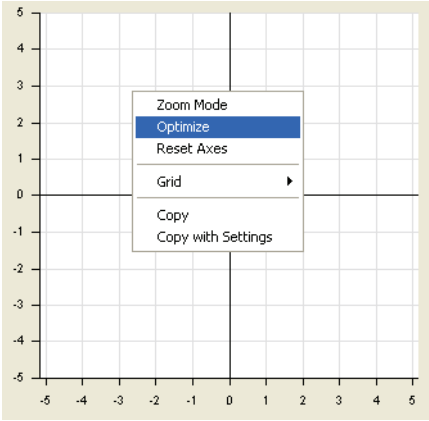
The connection diagram shows how to connect the DUT to the *Bode 100*.

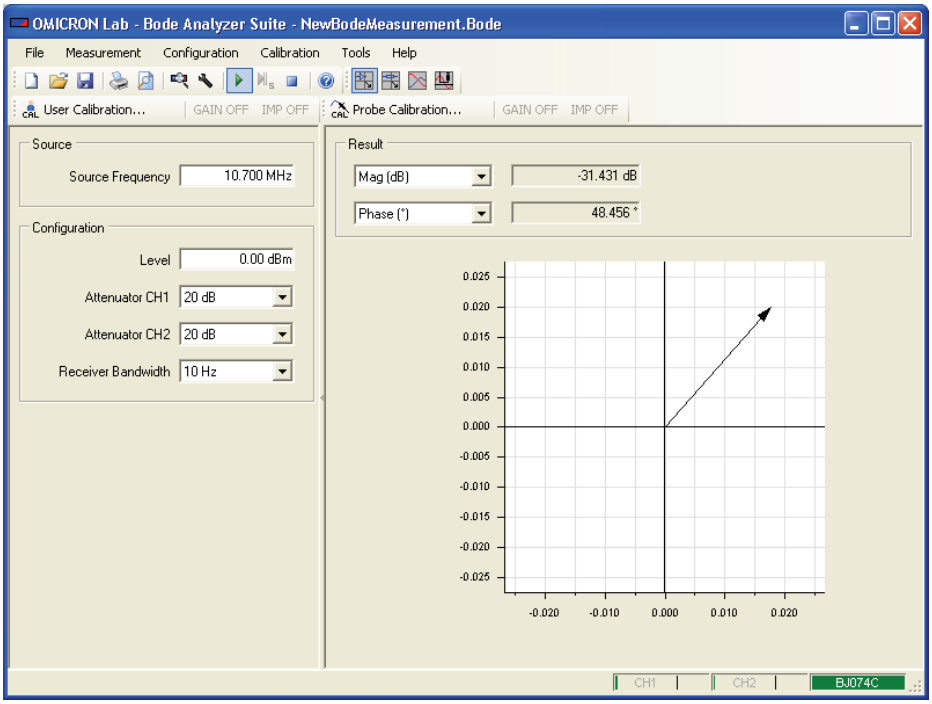
Hint: Set the voltage ratio in the box

if you use a probe instead of cable connection (see 9.2 "Advanced Sweep Options" on page 116).

6. Connect the IF filter to the *Bode 100* as shown.

7. Click OK to close the **Configuration** window and to get back to the **Gain/Phase** mode window.
8. For a better view of the **Gain/Phase** vector in the complex plane, right-click in the diagram, and then click **Optimize**.



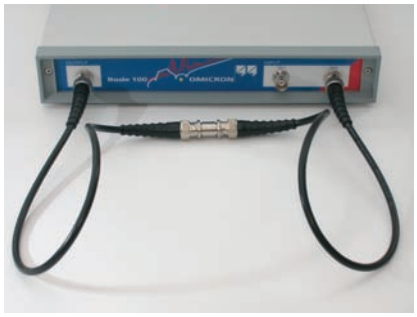


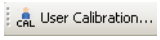
Result: The IF filter has a magnitude of –31.43 dB at 10.7 MHz. Your result may differ because each IF filter is slightly different.

The phase readout of 48.5º is not the value you want to measure because it is the sum of the phase shift of the cables and of the IF filter. To get the value of the IF filter only, use the **Gain/Phase** calibration to compensate the phase shift of the cables.

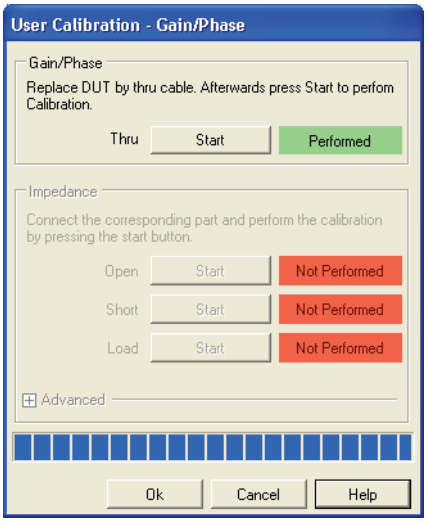
Continue the example and calibrate the *Bode 100* to get the phase shift of the IF filter:

1. Replace the IF filter with the BNC straight adapter (f–f).



2. Click the **User Calibration** toolbar button 

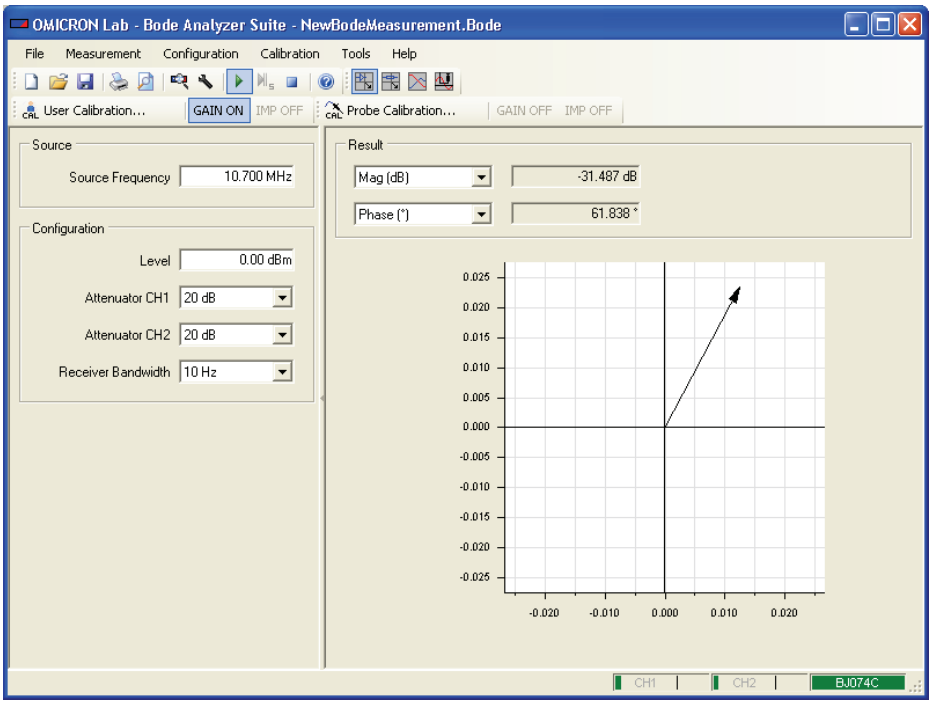
to open the calibration window.
3. In the calibration window, click **Start** in the **Gain/Phase** area.



The calibration takes only a few seconds. The **Gain/Phase** mode is now calibrated for the current specific measurement setup.

4. Click OK.
5. Reconnect the IF filter.

Hint: If you change settings you must repeat the **User Calibration**. If you use the **Probe Calibration** Probe Calibration... instead you can change settings without repeating the calibration. For more information, see 7 "Calibrating the Bode 100" on page 75.



Result: The transfer function of the IF filter has a magnitude of –31.49 dB and a phase shift of 61.8º at 10.7 MHz.

Again, your results may differ because every IF filter and measurement setup is slightly different.

Hint: You can toggle between the measurement results with calibration and without calibration by clicking the **GAIN ON** toolbar button GAIN ON.

As OMIfuzius said: Only applied knowledge changes the world. We are responsible to change it to the better.

Congratulation! You learned how to use the **Gain/Phase** mode.

How to:

- Measure the gain and phase shift of a DUT using a sinusoidal signal at a certain frequency
- Set the bandwidth, attenuators and amplitude of the *Bode 100*
- Optimize the diagram
- Compensate the connection cables in the **Gain/Phase** mode

Go back to the overview chart at 3 "Gain/Phase Mode" on page 17 and try different settings to check out their effect on the measurement.

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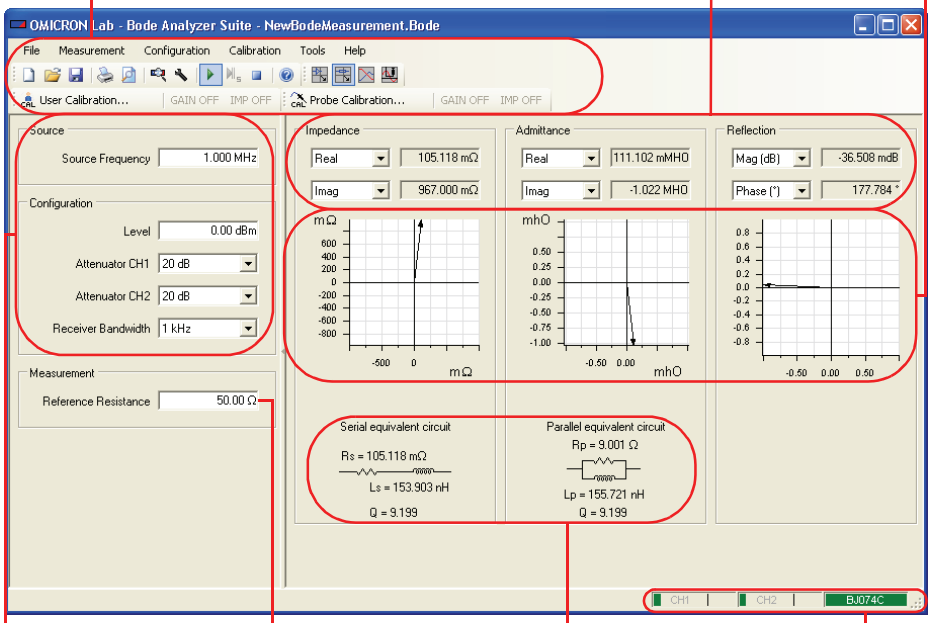
4 Impedance/Reflection Mode

Figure 4-1: **Impedance/Reflection** mode window

For the description of the menu bar, toolbar and calibration bar, see 8 "Common Functions" on page 95.

Graphical display of measurement results
Use the shortcut menu to optimize the display.
See Figure 3-4: "Graphical display of measurement results" on page 19.

Results
Select the result format and get result values.
See Figure 4-2: "Impedance/Reflection mode results" on page 34.



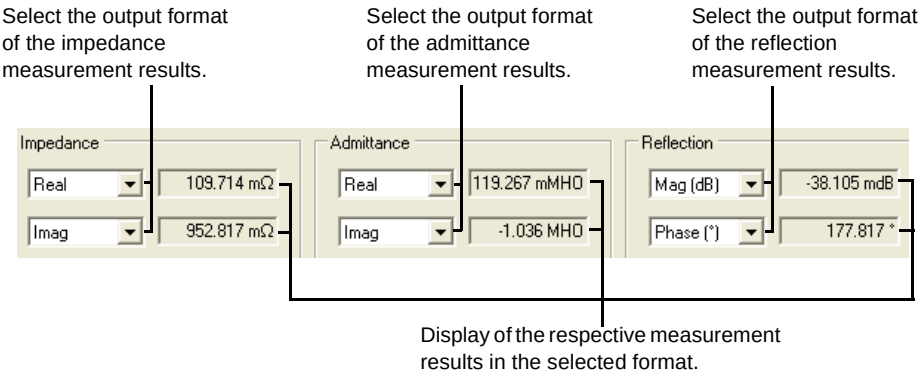
Equivalent circuits
View the equivalent circuits (see 4.1.2 "Equivalent Circuits" on page 35).

Reference resistance
Set the reference resistance (see 4.1.1 "General Formulas" on page 34).

Overload and connection indicators
See Figure 3-5: "Overload and connection indicators" on page 19.

Configuration and measurement setup
See Figure 3-2: "Configuration and measurement setup" on page 18.

Figure 4-2:
Impedance/Reflection mode results



4.1 Basics

4.1.1 General Formulas

The general formulas related to the **Impedance/Reflection** measurements are summarized below:

$$\underline{Z} = \frac{\underline{V}}{\underline{I}} \qquad \text{(Eq. 4-1)}$$

$$\underline{Y} = \frac{\underline{I}}{\underline{V}} = \frac{1}{\underline{Z}} \qquad \text{(Eq. 4-2)}$$

$$\underline{r} = \frac{\underline{Z} - R_0}{\underline{Z} + R_0} = \frac{G_0 - \underline{Y}}{G_0 + \underline{Y}} \qquad \text{(Eq. 4-3)}$$

$$VSWR = \frac{1 + |\underline{r}|}{1 - |\underline{r}|} \qquad \text{(Eq. 4-4)}$$

$$R_0 = \frac{1}{G_0} \qquad \text{(Eq. 4-5)}$$

where

$\underline{V}$	…voltage at the reference plane
$\underline{I}$	…current at the reference plane
$\underline{Z}$	…impedance
$\underline{Y}$	…admittance
$\underline{r}$	…reflection coefficient
$VSWR$	…voltage standing wave ratio
R_0	…reference resistance
G_0	…reference conductance

Note: The reference resistance R_0 can be set in the **Measurement** area of the **Impedance/Reflection** mode window.

4.1.2 Equivalent Circuits

The basic formulas for the serial equivalent circuit are:

$$\underline{Z} = \text{Real}(\underline{Z}) + j\text{Imag}(\underline{Z}) = R_s + jX_s \quad \text{(Eq. 4-6)}$$

$$R_s = \text{Real}(\underline{Z}) \quad \text{(Eq. 4-7)}$$

If $\text{Imag}(\underline{Z}) < 0$:

$$C_s = \frac{1}{\omega|\text{Imag}(\underline{Z})|} \quad \text{(Eq. 4-8)}$$

If $\text{Imag}(\underline{Z}) > 0$:

$$L_s = \frac{|\text{Imag}(\underline{Z})|}{\omega} \quad \text{(Eq. 4-9)}$$

where

R_s …series resistance
X_s …series reactance
C_s …series capacitance
L_s …series inductance

The basic formulas for the parallel equivalent circuit are:

$$\underline{Y} = \text{Real}(\underline{Y}) + j\text{Imag}(\underline{Y}) = \frac{1}{R_p} + j\left(\frac{-1}{X_p}\right) \quad \text{(Eq. 4-10)}$$

$$R_p = \frac{1}{\text{Real}(\underline{Y})} \quad \text{(Eq. 4-11)}$$

If $\text{Imag}(\underline{Y}) < 0$:

$$L_p = \frac{1}{\omega|\text{Imag}(\underline{Y})|} \quad \text{(Eq. 4-12)}$$

If $\text{Imag}(\underline{Y}) > 0$:

$$C_p = \frac{|\text{Imag}(\underline{Y})|}{\omega} \quad \text{(Eq. 4-13)}$$

where

R_p …parallel resistance
X_p …parallel reactance
L_p …parallel inductance
C_p …parallel capacitance

Depending on the regional settings of your computer the elements of the serial and parallel equivalent circuits are displayed according to the *IEC* (International Electronic Commission) or *ANSI* (American National Standards Institute) standards as shown below.

Figure 4-3:
Resistor and inductor symbols according to *ANSI*

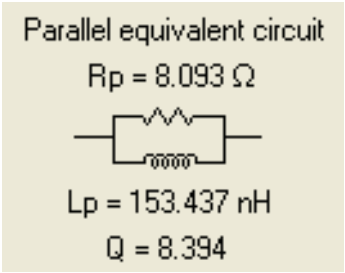
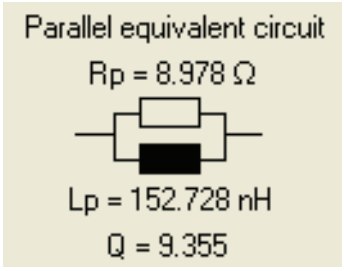


Figure 4-4:
Resistor and inductor symbols according to *IEC*



Note: Capacitors have the same symbol in both standards.

4.1.3 Quality Factor

An ideal inductor will be lossless irrespective of the amount of current flowing through the winding. An ideal capacitor will be lossless irrespective of the voltage applied to it. However, real inductors have a winding resistance due to the metal wire forming the coils and real capacitors have a resistance due to the used insulation material. These resistances cause a loss of inductive or capacitive quality. For serial equivalent circuits, the quality factor Q is defined as the ratio of the reactance to the resistance at a given frequency. For parallel equivalent circuits, the quality factor Q is defined as the ratio of the resistance to the reactance at a given frequency.The Q factor is a measure of the inductor's and capacitor's efficiency. The higher the Q factor of a capacitor or inductor, the closer the capacitor/inductor approaches the behavior of an ideal, lossless component.

The Q factor calculated using the serial equivalent circuit is given by

$$Q = \frac{|\mathrm{Imag}(\underline{Z})|}{\mathrm{Real}(\underline{Z})} = \frac{|X_s|}{R_s} \qquad \text{(Eq. 4-14)}$$

and using the parallel equivalent circuit is given by

$$Q = \frac{|\mathrm{Imag}(\underline{Y})|}{\mathrm{Real}(\underline{Y})} = \frac{\frac{1}{|X_p|}}{\frac{1}{R_p}} = \frac{R_p}{|X_p|} \qquad \text{(Eq. 4-15)}$$

4.2 Example: Impedance/Reflection Measurement

Expected example duration: 20 minutes.

In this example you will learn step by step how to use the **Impedance/Reflection** mode of the *Bode 100*.

How to:

- Measure the reflection coefficient at a frequency
- Set the bandwidth and amplitudes used for the measurement
- Connect the DUT for the impedance and reflection measurement
- Optimize the diagrams
- Work with the serial and parallel equivalent circuits

Question: What is the reflection coefficient in dB of the delivered IF filter input at 10.7 MHz?

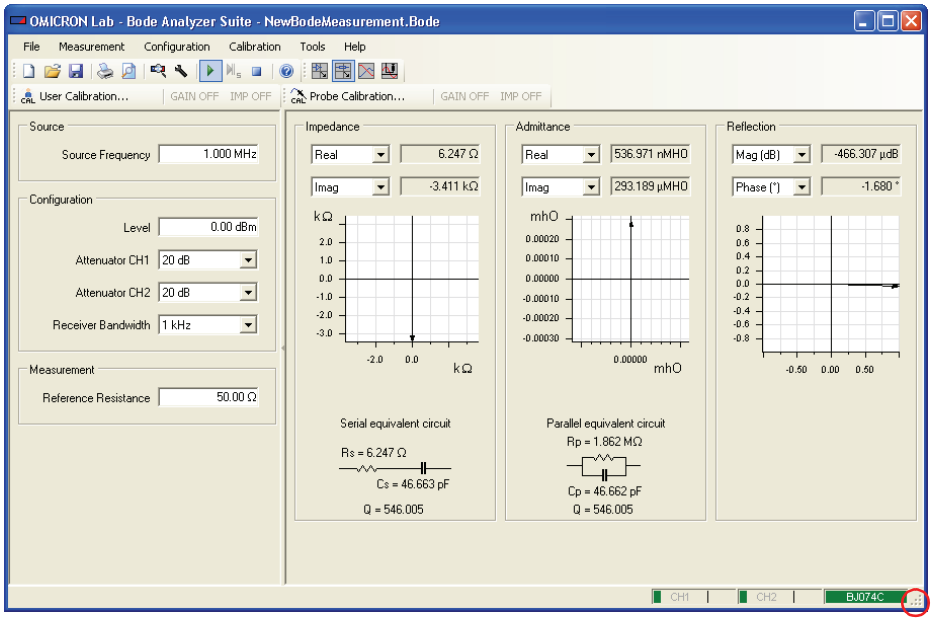
To find out the answer, proceed as follows:

1. Connect the *Bode 100* and start the *Bode Analyzer Suite*.

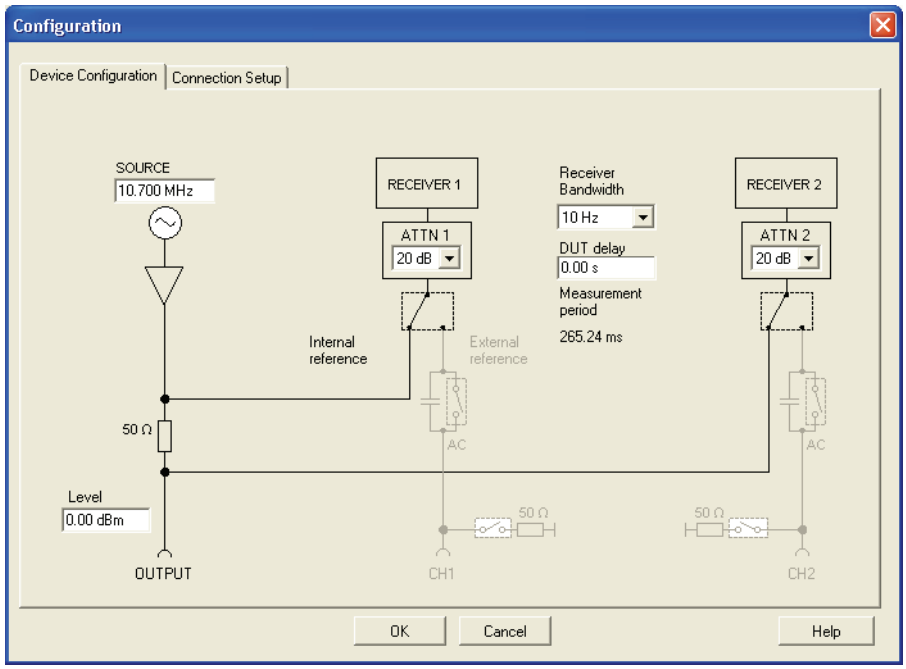
   Hint: If you see the serial number of your *Bode 100* on the lower right side of the status bar then your *Bode 100* is working properly.

2. Click the **Impedance/Reflection** toolbar button to switch to the **Impedance/Reflection** mode.

3. If necessary, adjust your window size. Move the mouse to the lower right corner of the window. By dragging the corner you can adjust the window.



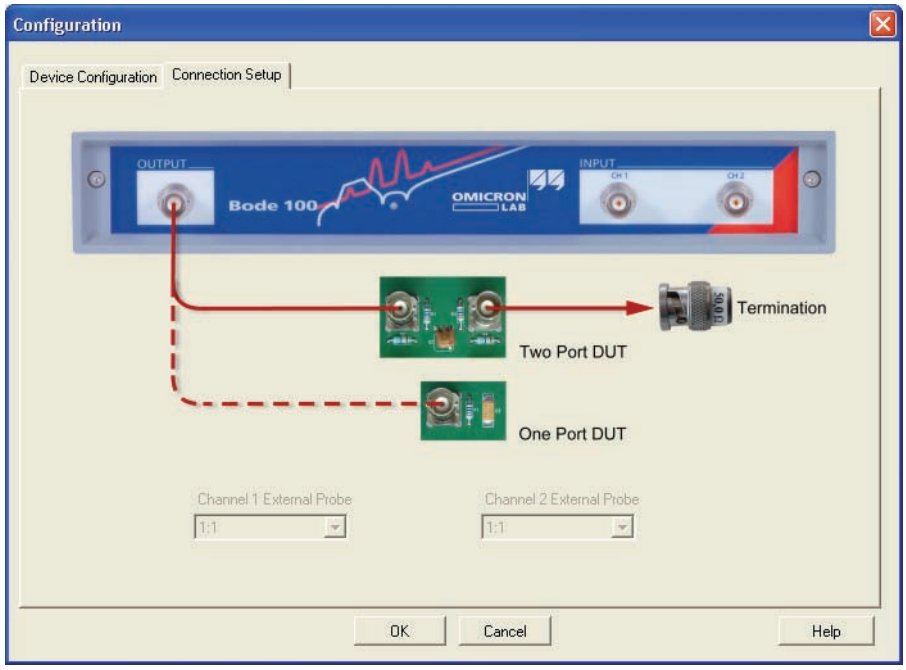
4. Click the **Device Configuration** toolbar button to configure the **Impedance/Reflection** mode.



5. Set:

- SOURCE: 10.7 MHz
- Receiver bandwidth: 10 Hz
- Level: 0 dBm

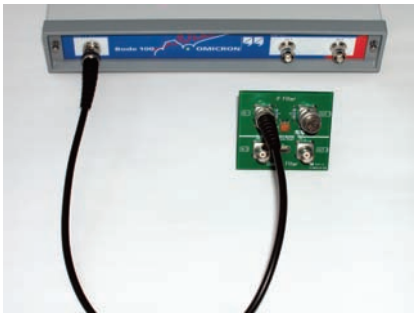
6. Click the **Connection Setup** tab.



The connection diagram shows how to connect the DUT to the *Bode 100*.

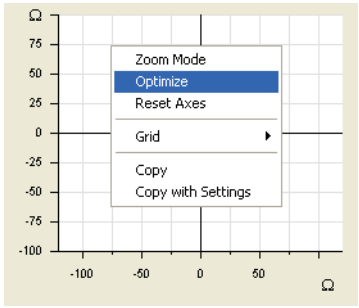
Hint: In the **Impedance/Reflection mode**, the channel 1 and channel 2 inputs are not used. Consequently, the **External Probe** boxes are unavailable.

7. Connect the output of the *Bode 100* to the input of the IF filter and the BNC 50 Ω load to the output of the IF filter as shown.

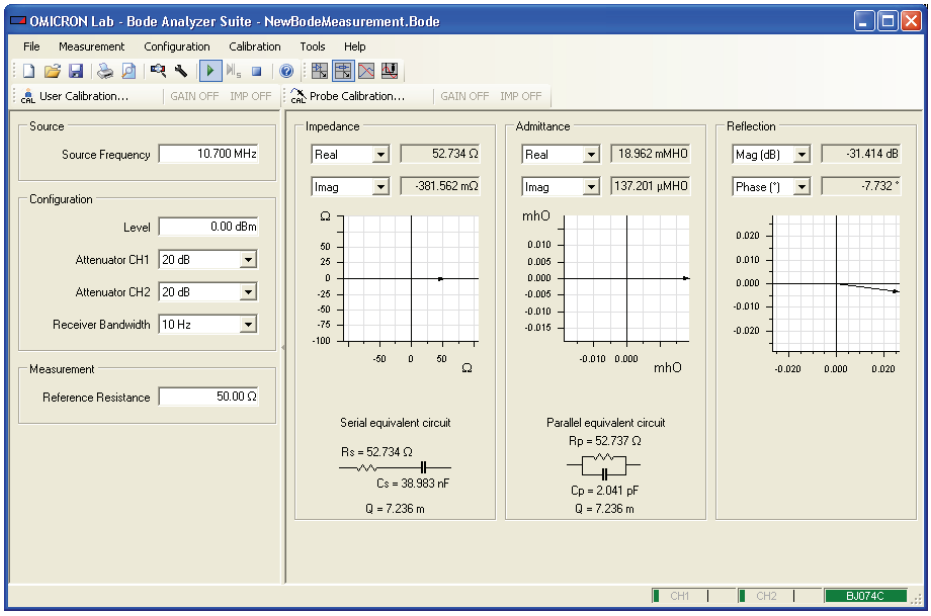


8. Click OK to close the **Configuration** window.

9. For a better view of the impedance, admittance and reflection vectors in the complex plane, right-click in the respective diagrams, and then click **Optimize**.



10. View the results.



Result: The measured values of the IF filter at 10.7 MHz are:

- Reflection coefficient: –31.4 dB
- Impedance: nearly 50 Ω

Again, your results may differ because every IF filter and measurement setup is slightly different.

Hint: To increase the size of the diagrams, make the window larger or hide the left pane by clicking the split bar. To restore the left pane, click the split bar again.

Hint: If you want to display the reflection in VSWR format select the **VSWR** output format under **Reflection** as shown below.

Usually, the reference resistance of 50 Ω is used to calculate the reflection coefficient and the VSWR. The **Reference Resistance** box allows you to enter other reference resistance values if required.

The parallel and serial equivalent circuits give us an indication of the electrical components that would be required to rebuild the electrical characteristics of your DUT at the measurement frequency. In our example you would require a 39 nF capacitor and a 52.7 Ω resistor to build the series equivalent circuit.

Try it out, get yourself the required components and repeat the measurement. If the results do not match 100% keep in mind that you are using real components with a Q factor on their own.

For information on how to calibrate the *Bode 100* in the **Impedance/Reflection** mode, see 7.4 "Calibration in the Impedance/Reflection Mode" on page 83.

Congratulation! You learned how to use the **Impedance/Reflection** mode.

How to:

- Measure the reflection coefficient at a frequency
- Set the bandwidth and amplitudes used for the measurement
- Connect the DUT for the impedance and reflection measurement
- Optimize the diagrams
- Understand serial and parallel equivalent circuits

Go back to the overview chart at 4 "Impedance/Reflection Mode" on page 33 and try things out.

After this example get a glass of water to increase your reflection mode and your attention bandwidth. Then try things out and right-click and left-click to everything that does not move on the screen.

5 Frequency Sweep Mode

Figure 5-1:
Frequency Sweep mode window

Sweep settings
Set frequency sweep.
See Figure 5-2: "Sweep settings" on page 44.

Cursor settings
Set cursors and view measurement results.
See Figure 5-3: "Cursor settings" on page 44.

Trace settings
Define measurement format and display options.
See Figure 5-4: "Trace settings" on page 45.

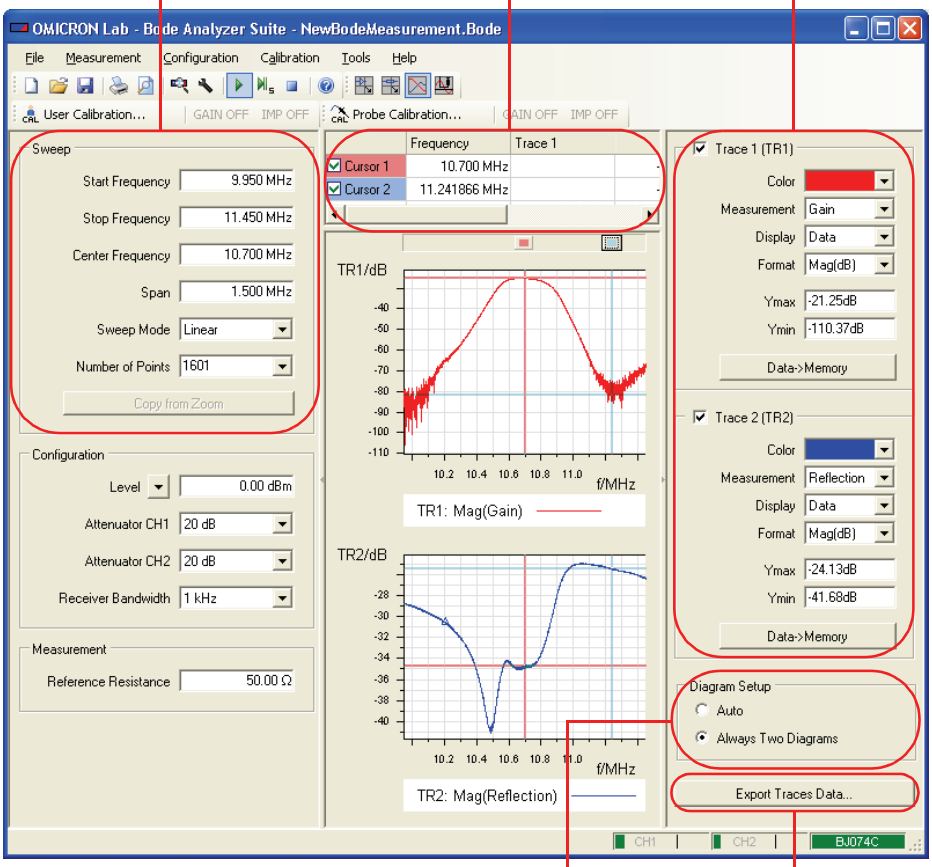


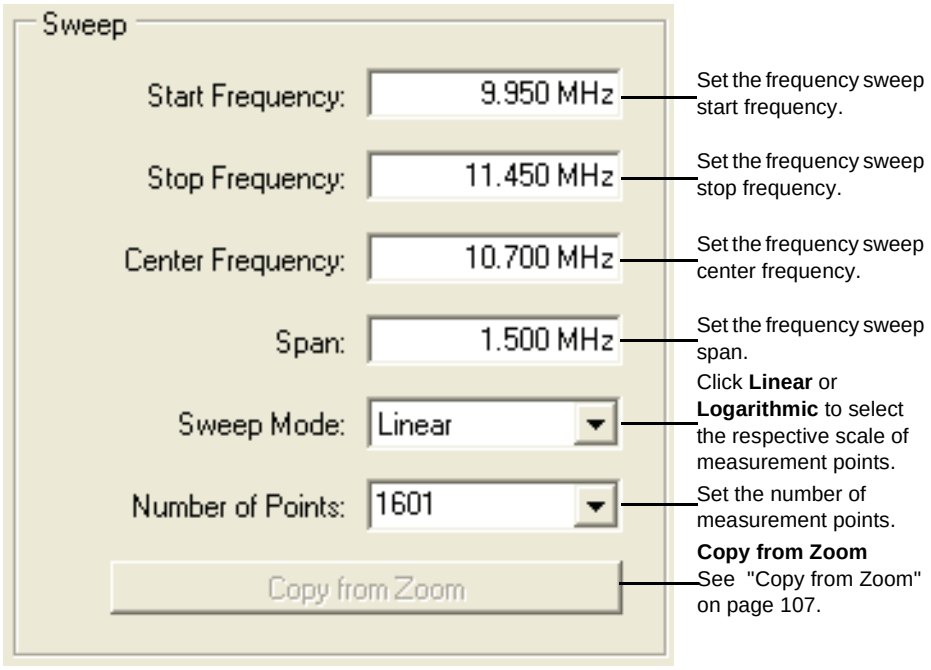
Diagram setup
See Figure 5-5: "Diagram setup" on page 46.

Export traces data
Export traces as CSV file.
See 8.3.2 "Exporting Measurement Data" on page 99.

Note: Only window areas specific for the **Frequency Sweep** mode are explained. For window areas common to other measurement modes, see Figure 3-1: "Gain/Phase mode window" on page 17 and Figure 4-1: "Impedance/Reflection mode window" on page 33.

In the **Frequency Sweep** mode you can perform a sequence of **Gain/Phase** and/or **Impedance/Reflection** measurements and examine the results in different types of diagrams.

Figure 5-2:
Sweep settings



Hint: The start frequency, stop frequency, center frequency and span are mutually dependent. After one of them has been changed, the others settings are recalculated by the *Bode Analyzer Suite*.

Figure 5-3:
Cursor settings

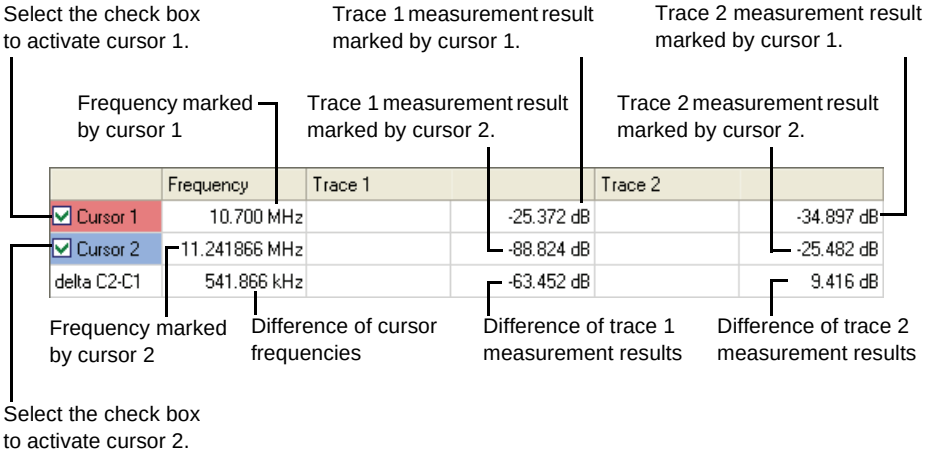

Select the check box to activate cursor 1.
Trace 1 measurement result marked by cursor 1.
Trace 2 measurement result marked by cursor 1.
Frequency marked by cursor 1
Trace 1 measurement result marked by cursor 2.
Trace 2 measurement result marked by cursor 2.
Frequency
Trace 1
Trace 2
Cursor 1
10.700 MHz
-25.372 dB
-34.897 dB
Cursor 2
11.241866 MHz
-88.824 dB
-25.482 dB
delta C2-C1
541.866 kHz
-63.452 dB
9.416 dB
Frequency marked by cursor 2
Difference of cursor frequencies
Difference of trace 1 measurement results
Difference of trace 2 measurement results
Select the check box to activate cursor 2.

Figure 5-4:
Trace settings

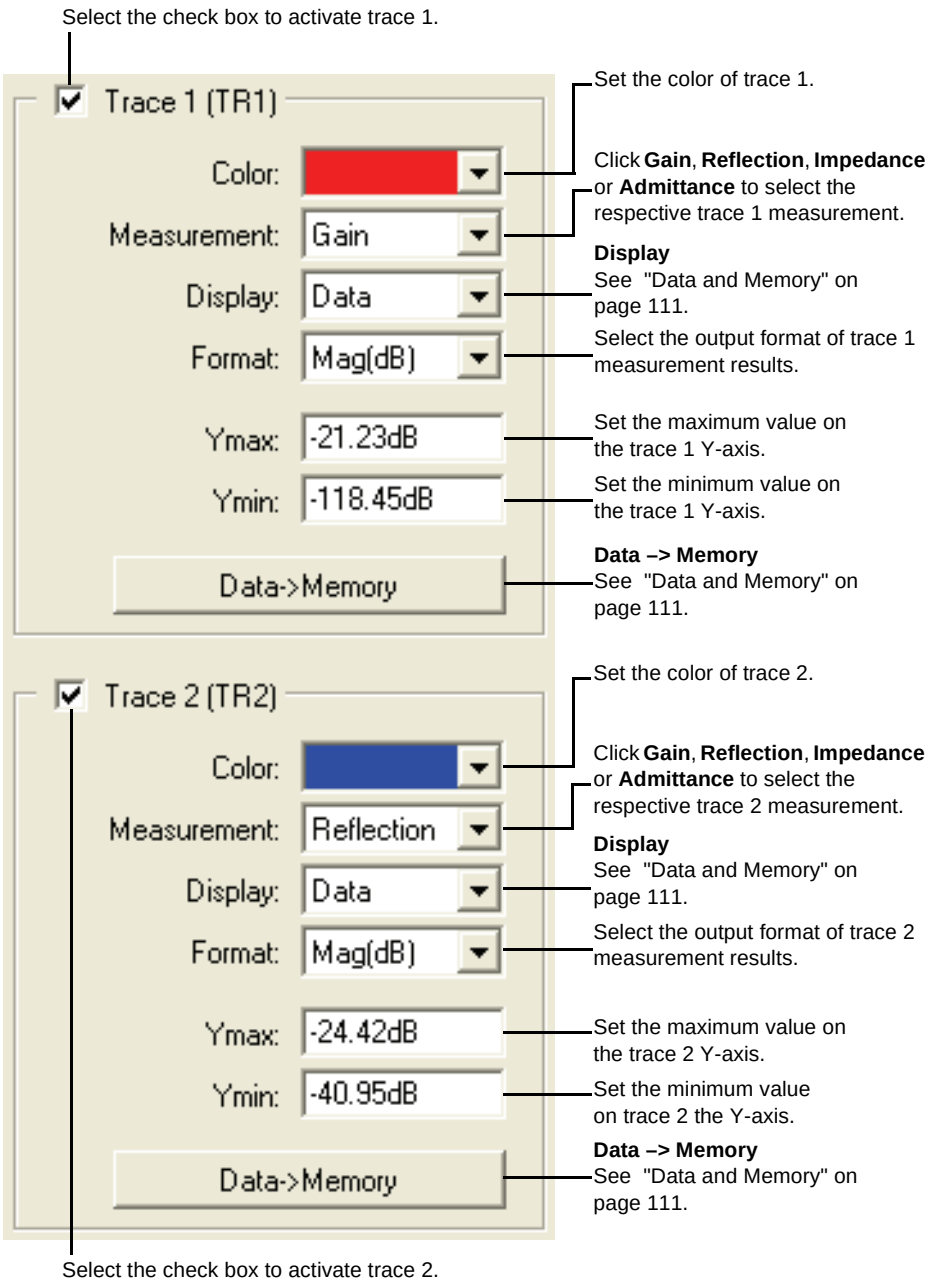
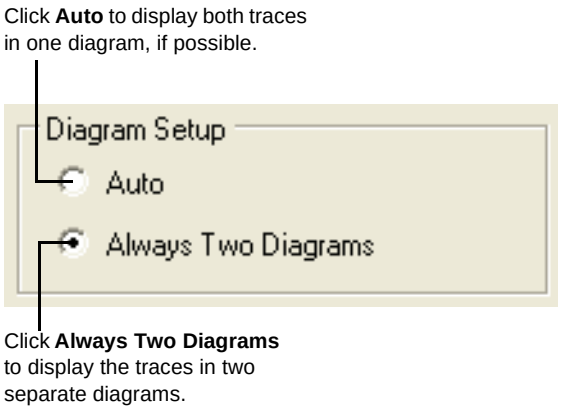


Figure 5-5:
Diagram setup


Click **Auto** to display both traces in one diagram, if possible.
Diagram Setup
Auto
Always Two Diagrams
Click **Always Two Diagrams** to display the traces in two separate diagrams.

Note: Diagram Setup is only available if both traces are activated.

5.1 Example: Frequency Sweep Measurement

Expected example duration: 30 minutes.

In this example you will learn step by step how to use the **Frequency Sweep** mode of the *Bode 100*.

How to:

- Visualize measurement data in a graph
- Set configuration parameters like the input resistor and bandwidth
- Set sweep parameters like start and stop frequencies
- Use cursors to read single measurement points
- Calibrate and compensate the cables

Let's examine the12 MHz quartz filter on the delivered printed circuit board (PCB).

Questions:

- How does the gain of the quartz filter look if displayed as a function of frequency?
- How does the reflection coefficient of the quartz filter look in the Smith chart?
- What are the series resonance and the parallel resonance frequencies?
- What is the attenuation of the quartz filter at its series resonance?
- What is the group delay T_g of the quartz filter at its series resonance?
- What is the series resistance R_S of the quartz filter?

To find out the answers, proceed as follows:

1. Connect the *Bode 100* to the computer and start the *Bode Analyzer Suite*.

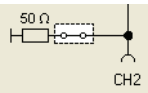
   Hint: If you see the *Bode 100* serial number on the lower right side of the status bar then your *Bode 100* is working properly.

2. Click the **Frequency Sweep** toolbar button to switch to the **Frequency Sweep** mode.

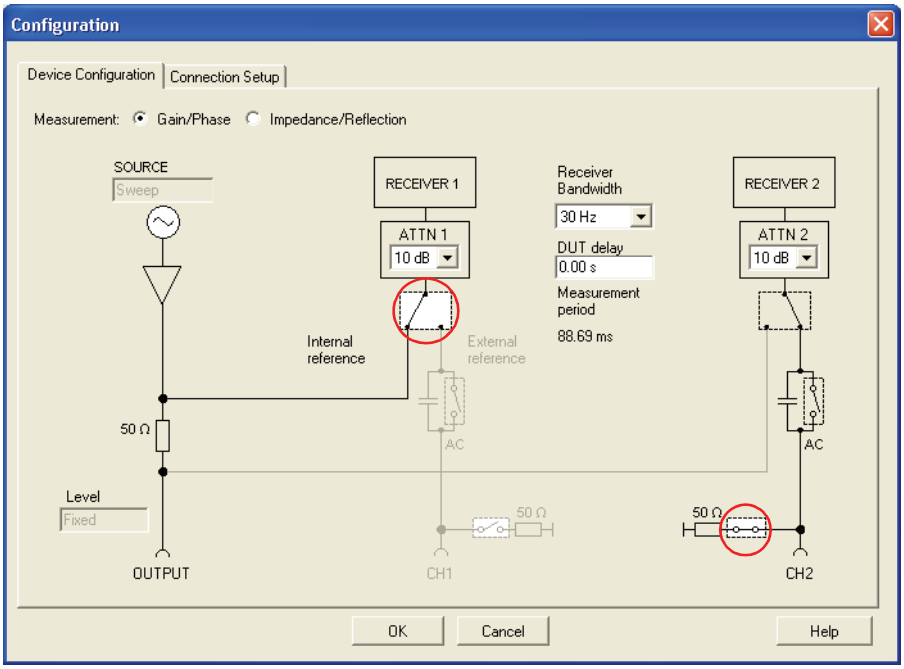
3. Click the **Device Configuration** toolbar button to configure the **Frequency Sweep** mode.
   We want to measure the quartz filter with 50 Ω load.

4. Set:

- CH2: 50 Ω ON (click the switch as shown)



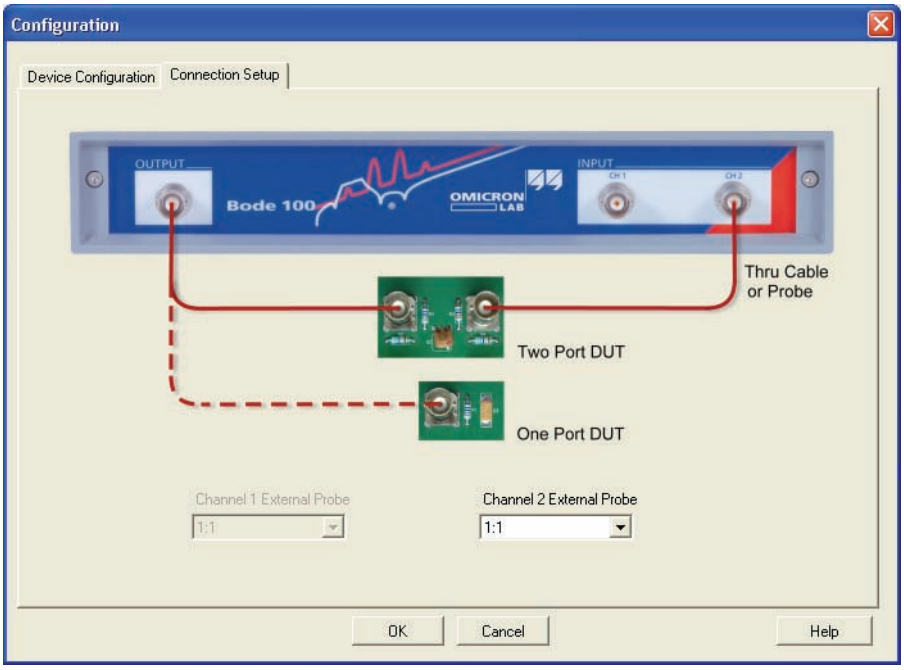
- The switch (before ATTN1) to the internal source as reference



Hint: In the **Frequency Sweep** mode, the *Bode 100* can measure the gain/phase as well as the impedance/reflection of the DUT versus frequency. The **Gain/Phase** and **Impedance/Reflection** buttons in the **Configuration** window are just used to show the respective device configurations. The buttons have no impact on the measurements performed by the *Bode 100* – you select the measurement in the **Measurement** lists in the **Trace 1** and **Trace 2** areas (see Figure 5-4: "Trace settings" on page 45). To see the device configuration the *Bode 100* uses for the **Impedance/Reflection** measurement just click the **Impedance/Reflection** button.

Hint: With a narrow receiver bandwidth like 30 Hz, the measurement is very selective. Only little noise will affect the measurement and, consequently, the measurements will be more stable but the sweep will be slow. The receiver bandwidth of 3 kHz will perform the fastest sweep.

5. Click the **Connection Setup** tab.

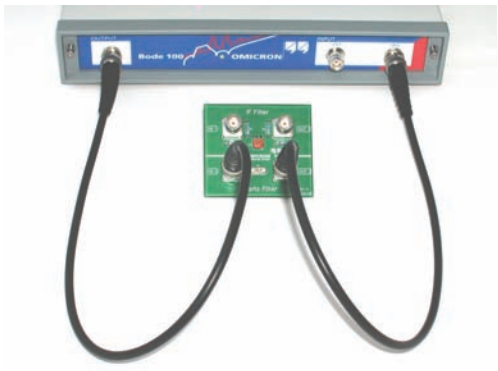


The connection diagram shows how to connect the DUT to the *Bode 100*.

Hint: Use the

box to set the voltage ratio when you use a probe instead of cable connection (see 9.4 "Using Probes" on page 125).

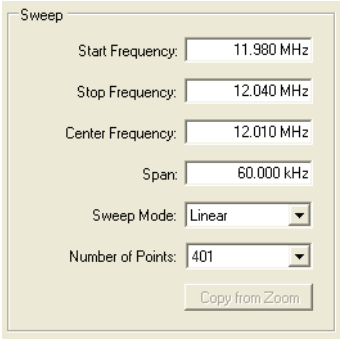
6. Connect the quartz filter to the *Bode 100* as shown.



7. Click OK to close the **Configuration** window and to get back to the **Frequency Sweep** mode window.
8. Set the sweep frequencies:

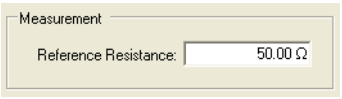
- Start frequency: 11.98 MHz
- Stop frequency: 12.04 MHz
- Number of points: 401

The other settings will be automatically calculated and the **Sweep** area of the **Frequency Sweep** mode window should now look like below.



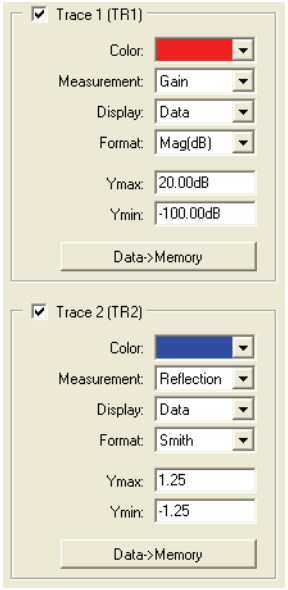
Hint: A setting which results in an out-of-range frequency for any other parameter will be corrected to ensure that all sweep frequencies (start, stop, center) are within the range of 10 Hz…40 MHz or 1 Hz…40 MHz if you selected the extended measurement range (see 8.2 "Setting the Measurement Range" on page 98).

9. Set the reference resistance.
Default: 50 Ω



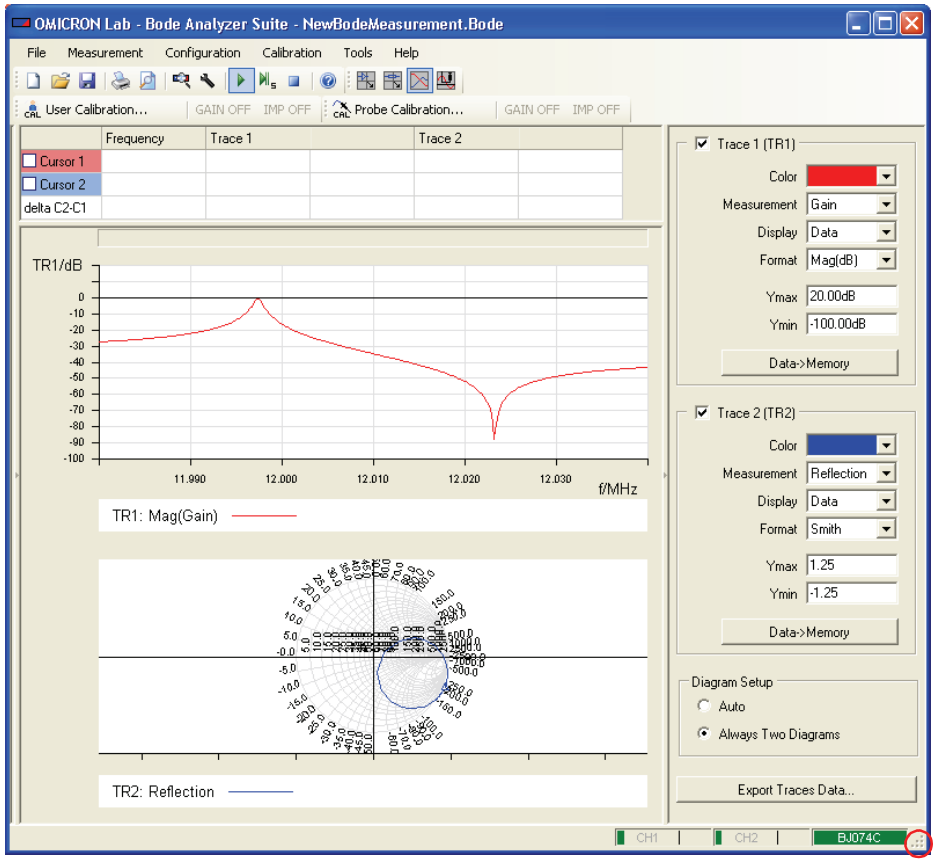
The reference resistance is used to calculate the reflection coefficient and the VSWR.

10. Activate both traces and set the parameters as shown below.



11. If you have a larger screen you can adjust your window size. Move the mouse to the lower right corner of the window . and drag the corner.

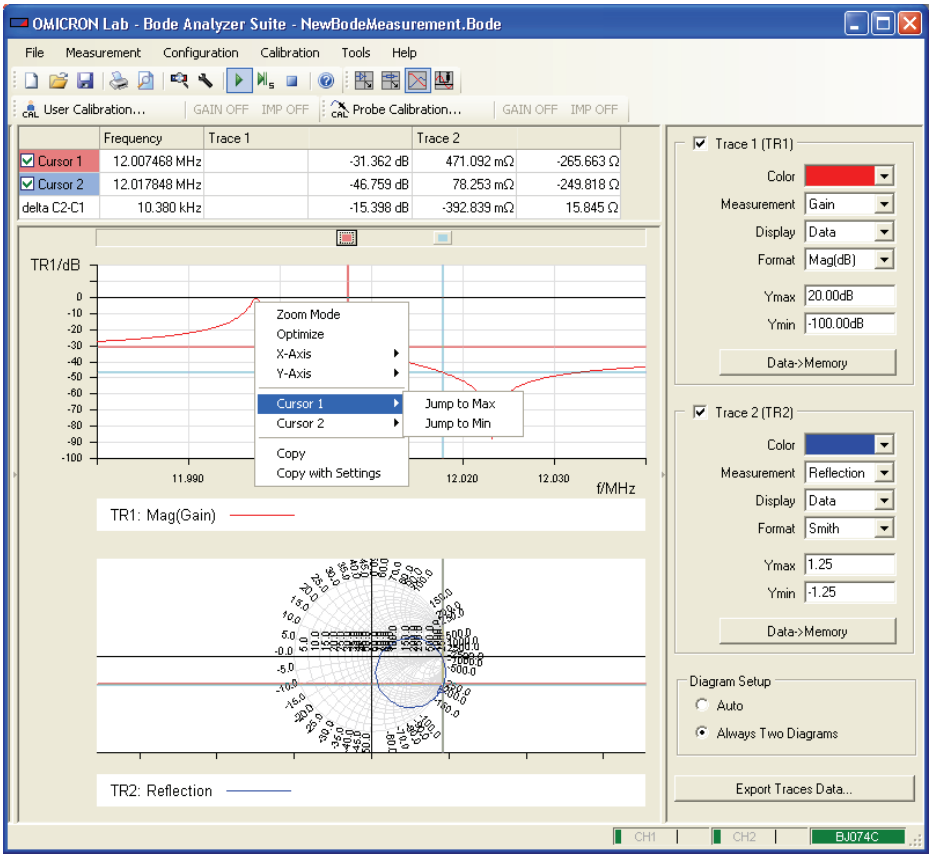
Hint: In addition to resizing the window, you can click the split bar to hide the left and right panes to increase the size of the diagrams.



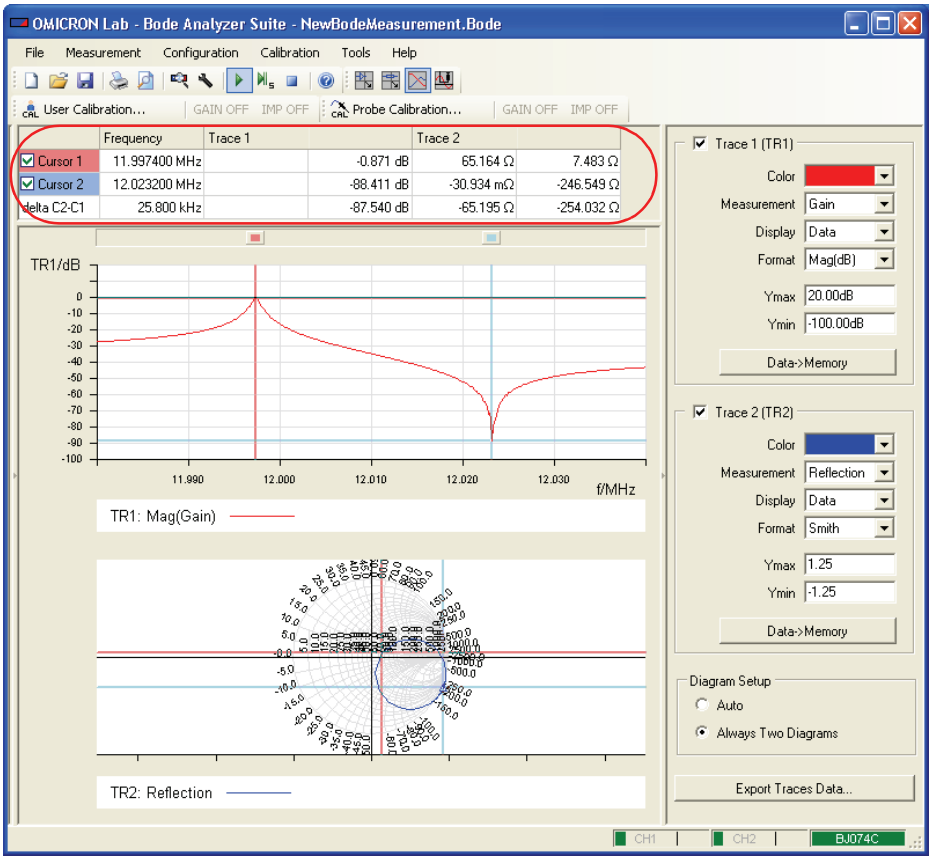
In the upper graph you see the gain of the quartz filter. You can use the cursors to measure the series and parallel resonance frequencies.

12. Select the **Cursor 1** and **Cursor 2** check boxes to activate the cursors.

13. To find the series resonance frequency of the quartz filter, right-click the curve in the upper diagram, point to **Cursor 1**, and then click **Jump to Max**.

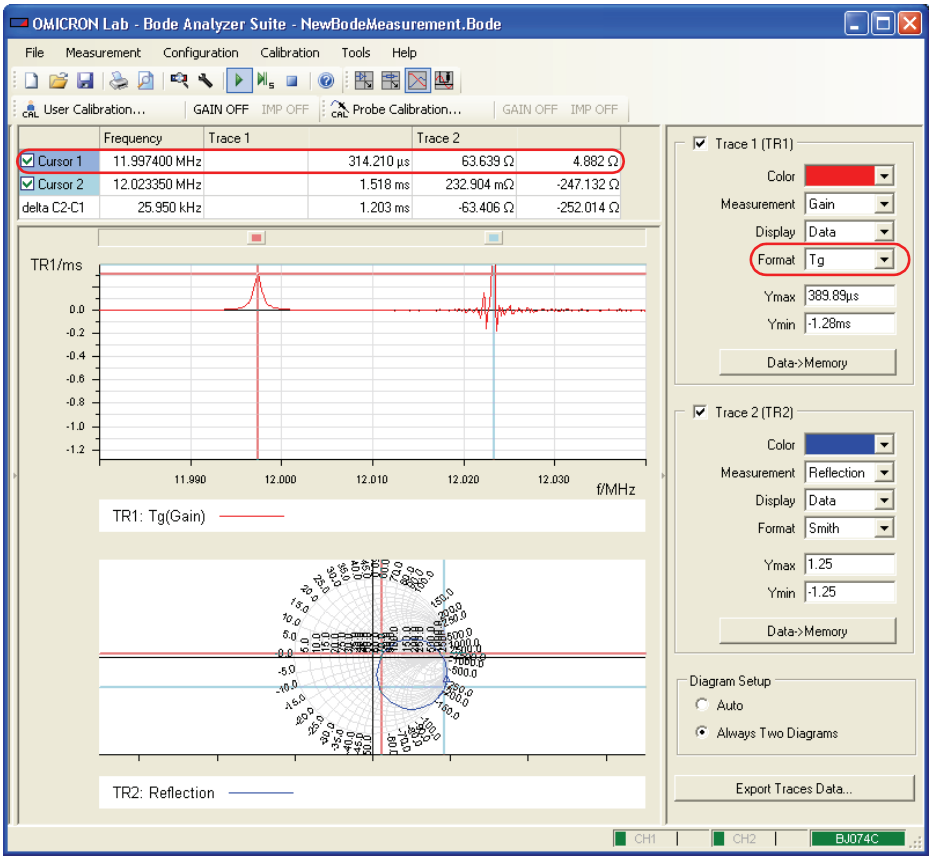


14. To find the parallel resonance frequency of the quartz filter, right-click the curve in the upper diagram, point to **Cursor 2**, and then click **Jump to Min**. In the marked area of the **Frequency Sweep** mode window, the series and parallel resonance frequencies and the corresponding measurement data are now displayed.



Results: Cursor 1 marks the series resonance frequency of 11.997 MHz and an attenuation at the series resonance frequency of 0.871 dB.
Cursor 2 marks the parallel resonance frequency of 12.023 MHz and an attenuation at the parallel resonance frequency of 87.725 dB.

15. To measure the group delay of the quartz filter at its series resonance frequency, select **Tg** in the **Format** list.
    The following figure shows the group delay measured by **Trace 1** at the series resonance frequency marked by cursor 1.



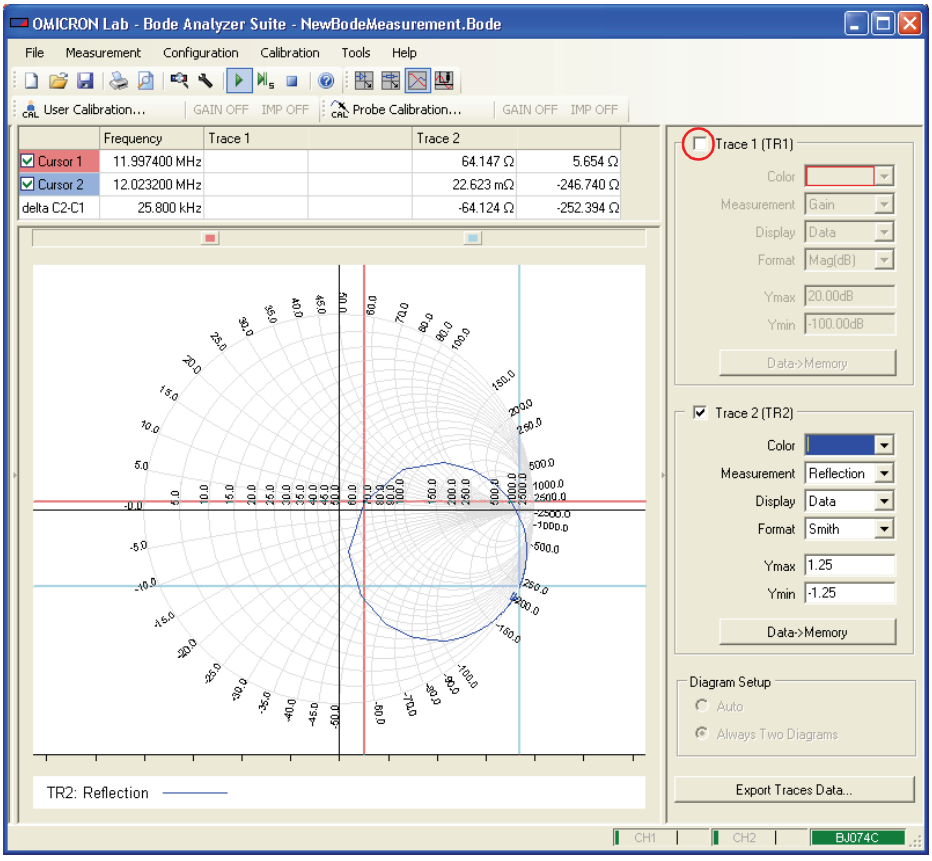
Result: The group delay T_g at the series resonance frequency of the quartz filter is 314.2 µs. Due to the high attenuation at the parallel resonance frequency it is not possible to measure the group delay at the quartz filter's parallel resonance.

Your result might be slightly different because even quartz filters show variations in their electrical characteristics.

16. For the measurement of the series resistance of the quartz filter we will use the Smith chart. The Smith chart displays the reflection coefficient (see (Eq. 4-3) on page 34) in the complex plane. The horizontal axis represents the real component and the vertical axis the imaginary component of the DUT's reflection coefficient. The central point of the Smith chart corresponds to the

case when the DUT's impedance equals the reference resistance and, consequently, the reflection coefficient is zero.
Additionally, the Smith chart contains circles with constant resistance (R) and constant reactance (X). This diagram format allows an easy "translation" of any point of the reflection coefficient curve into the corresponding DUT's impedance. The cursor values displayed in the Smith chart format are the real and imaginary components of the corresponding DUT's impedance. For more information on the Smith chart, refer to the relevant technical literature.

17. In the lower graph you see the Smith chart showing the reflection coefficient of the quartz filter. To display only this chart, clear the **Trace 1** check box to deactivate trace 1.

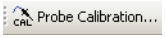


Since the output of the DUT (quartz filter) is connected to the channel 2 input, the measured impedance is the quartz impedance plus the 50 Ω input impedance of the *Bode 100*.

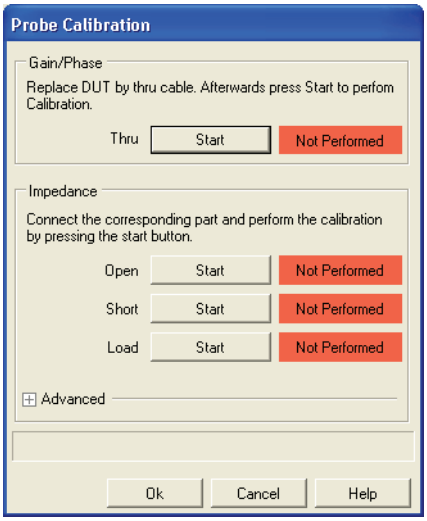
For an idle quartz, the trace should be nearly symmetrical against the real axis. The reason why it is not is as follows: We have used a cable to connect the quartz filter to the *Bode 100* and therefore we measure a phase shift of the reflected voltage (twice the shift of the cable itself). We can remove this unwanted phase shift by using the **Impedance** calibration. By calibrating the *Bode 100* we move the **Impedance/Reflection** reference plane to the end of the cable connected to the input of the DUT.

5.2 Impedance Calibration

Now we perform the **Impedance** calibration. This type of calibration is also described in 7.4 "Calibration in the Impedance/Reflection Mode" on page 83.

1. Click the **Probe Calibration** toolbar button 

to open the calibration window.



2. Connect the cable you want to use for the measurement to the OUTPUT connector of the *Bode 100*. Plug the BNC straight adapter on the other end of the cable.

3. Click the **Start** button next to **Open** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

With the measurement settings the calibration may take about 35 seconds.

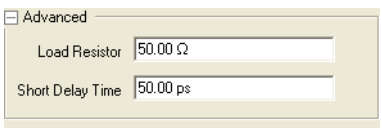
Hint: You can reduce the calibration time by setting fewer measurement points, a wider receiver bandwidth, or by choosing the **Probe Calibration**.

4. Plug the BNC short circuit on the straight adapter connected to the cable.

5. Click the **Start** button next to **Short** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

6. Replace the BNC short circuit with the BNC 50 Ω load.

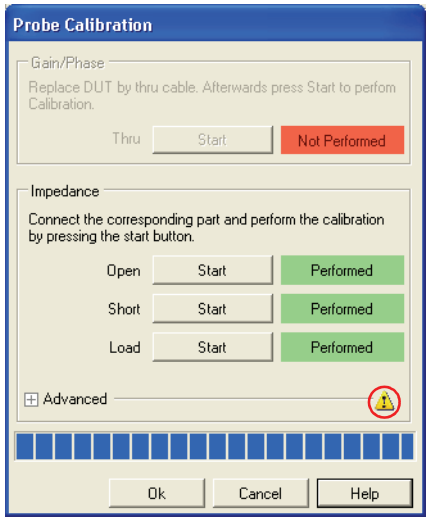
7. For very accurate measurements or if you use a load resistor different from 50 Ω, click the + symbol next to **Advanced**, and then enter the exact resistance of the load resistor.



Hint: For more information on the advanced calibration settings, see 7.4 "Calibration in the Impedance/Reflection Mode" on page 83.

8. Click the **Start** button next to **Load** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

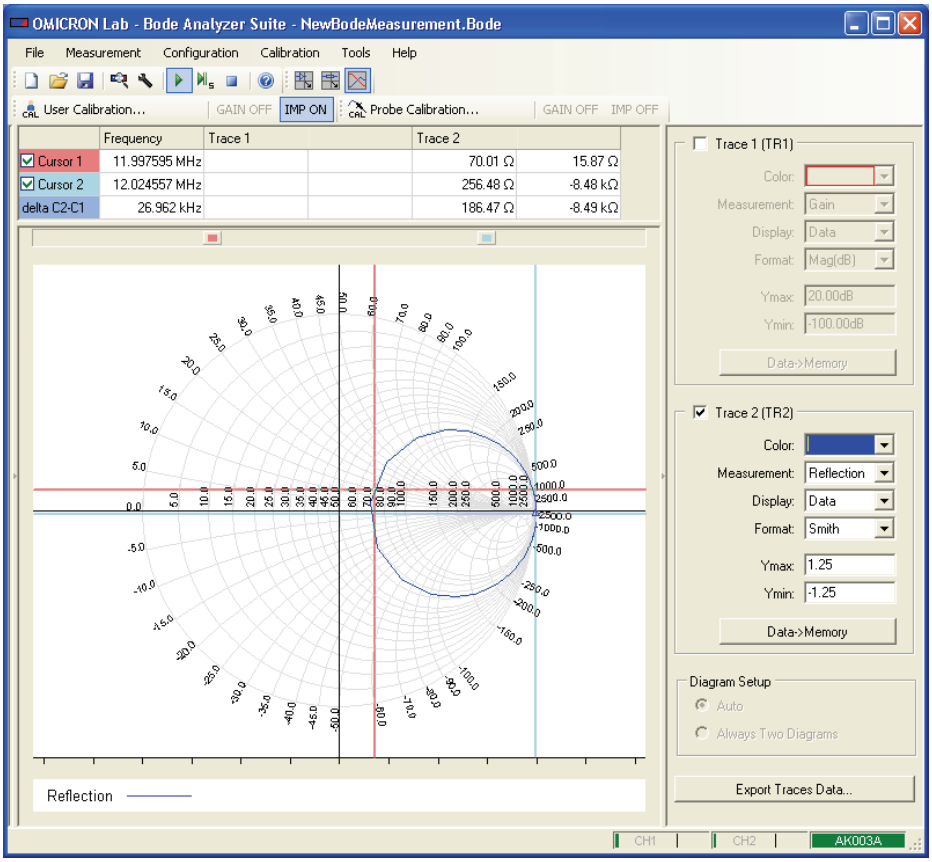
9. After the calibration has been finished, the calibration window looks like shown below.



Hint: The warning symbol indicates that the load resistor and/or the short delay time value differ from the factory settings.

10. Click OK. You have done the **Impedance** calibration in the **Frequency Sweep** mode.
11. Reconnect the quartz filter to the *Bode 100* as shown below.

12. View the calibrated Smith chart.



13. Calculation of the series resistance R_S at the series resonance frequency:
    To calculate the series resistance of the quartz filter you need to subtract 50 Ω from the real part measured with cursor 1. The reason for this is that the reflection measurement circuit "sees" the quartz filter in series with the 50 Ω termination of the channel 2 input.
    The **Trace 2** columns of the table display the real and imaginary parts of the measurement results at the frequencies marked by the cursors.

Result: R_S = 70.01 Ω – 50 Ω = 20.01 Ω

Your result may slightly differ because every quartz filter and measurement setup is different.

Frequency sweepers have an easier time to get the picture.

Congratulation! You learned how to use the **Frequency Sweep** mode.

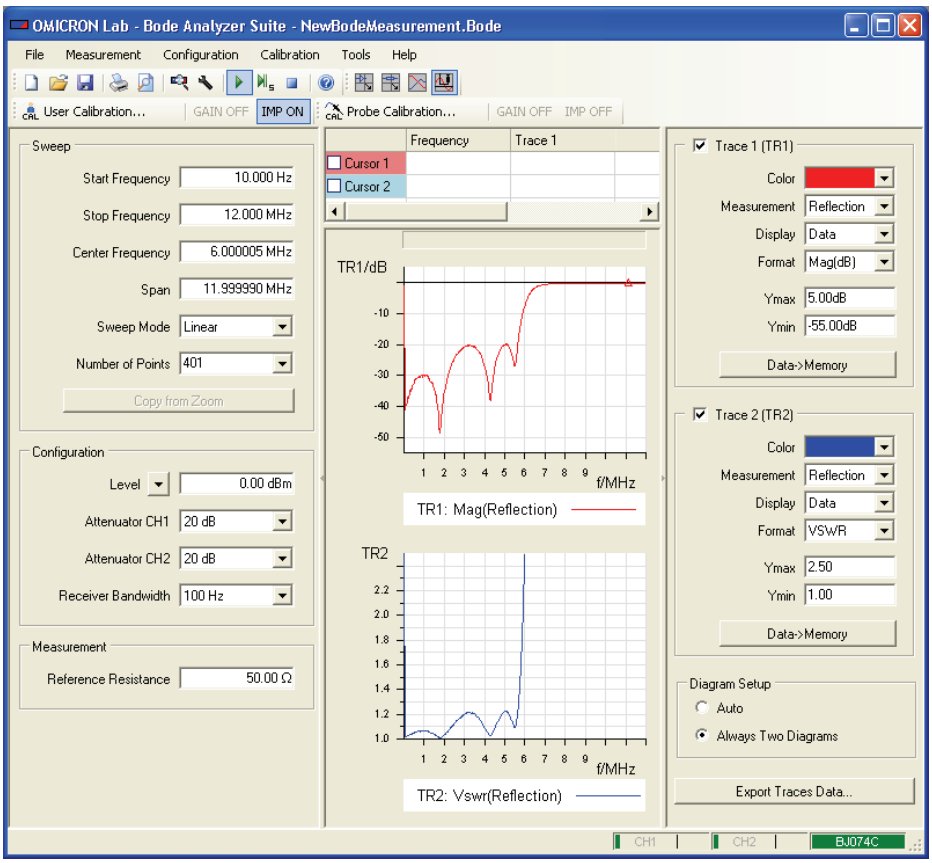
How to:

- Visualize measurement data in a graph
- Set configuration parameters like the input resistor and bandwidth
- Set sweep parameters like start and stop frequencies
- Use cursors to read single measurement points
- Calibrate and compensate for the cable

Go back to the **Frequency Sweep** mode window in 5 "Frequency Sweep Mode" on page 43 and try things out.

6 Frequency Sweep (External Coupler) Mode

Figure 6-1:
Frequency Sweep (External Coupler) mode window



Note: The window areas and screen elements in the **Frequency Sweep (External Coupler)** mode are the same as in the **Frequency Sweep** mode. For their description, see Figure 5-1: "Frequency Sweep mode window" on page 43.

In the **Frequency Sweep (External Coupler)** mode you can perform a sequence of **Impedance/Reflection** measurements by using an external directional coupler only or in combination with an external amplifier.

For some impedance measurement applications, it is beneficial to use external couplers for an optimum adaptation of the *Bode 100* to the test object (see Figure 6-2: "Connecting external coupler" below). Further on, impedance measurements on some test objects such as medium wave antenna systems require higher signal levels than provided by the *Bode 100*. By using an external coupler it is possible to utilize an external amplifier to boost the *Bode 100* source signal to the required output level (see Figure 6-3: "Connecting external coupler and amplifier" below).

Figure 6-2: Connecting external coupler

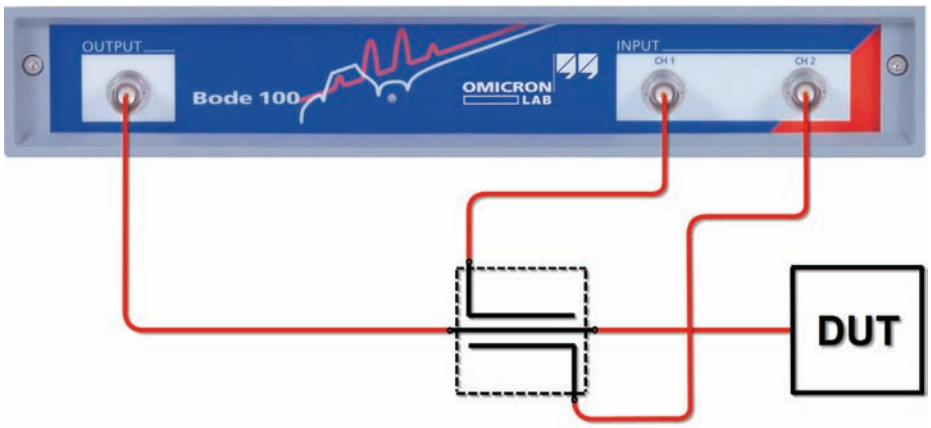
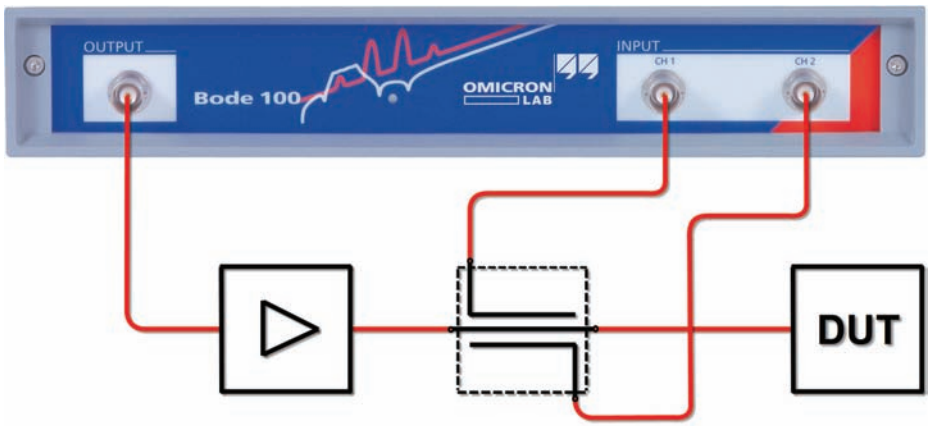


Figure 6-3: Connecting external coupler and amplifier



Hint: By using an external amplifier and an external coupler you can protect the *Bode 100* inputs from reverse power emitted by the DUT (e.g. radio waves received by a broadcast antenna).

6.1 Example: Frequency Sweep (External Coupler) Measurement

Expected example duration: 30 minutes.

In this example you will learn step by step how to use the **Frequency Sweep (External Coupler)** mode of the *Bode 100*.

How to:

- Connect an external coupler
- Set configuration parameters like the input resistor and bandwidth
- Calibrate and compensate the connection system
- Display reflection in VSWR format
- Display impedance in polar format
- Remove the effect of noise

Let's examine the delivered IF filter when connected to the *Bode 100* by a 50 Ω directional coupler.

Questions:

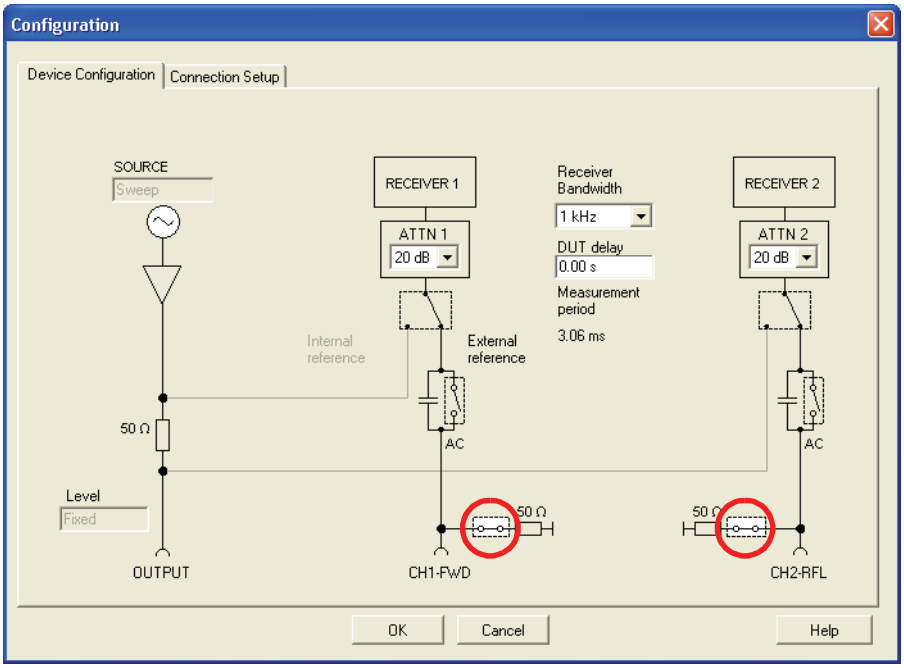
- What is the VSWR of the IF filter within its passband?
- How does the impedance of the IF filter look in the polar format?
- What is the exact impedance and VSWR of the filter at its center frequency of 10.7 MHz?

To find out the answers, proceed as follows:

1. Connect the *Bode 100* to the computer and start the *Bode Analyzer Suite*.
2. Click the **Frequency Sweep (External Coupler)** toolbar button to switch to the **Frequency Sweep (External Coupler)** mode.
3. Click the **Device Configuration** toolbar button to configure the **Frequency Sweep (External Coupler)** mode.

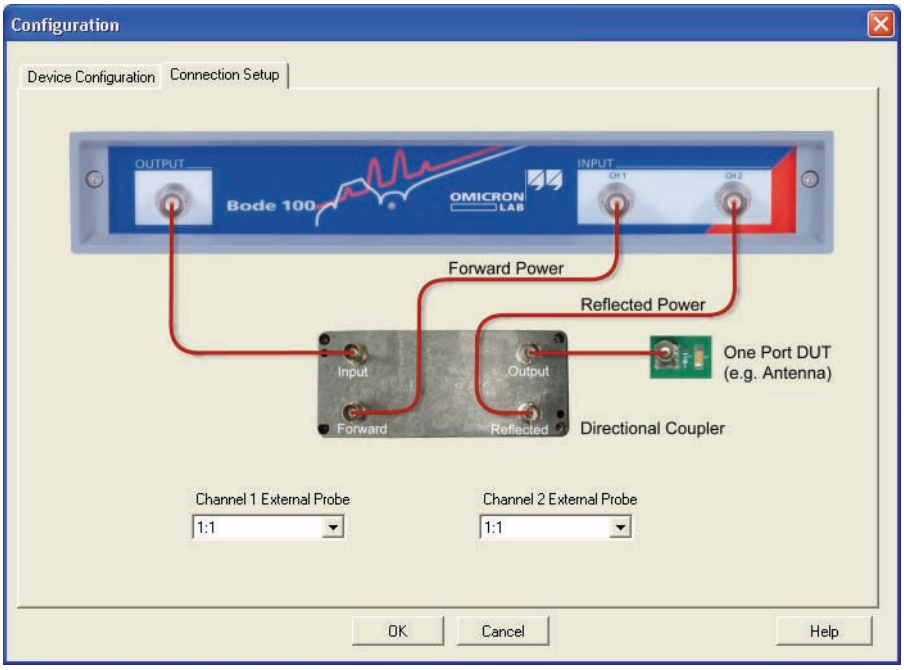
4. Set:

- CH1: 50 Ω ON
- CH2: 50 Ω ON



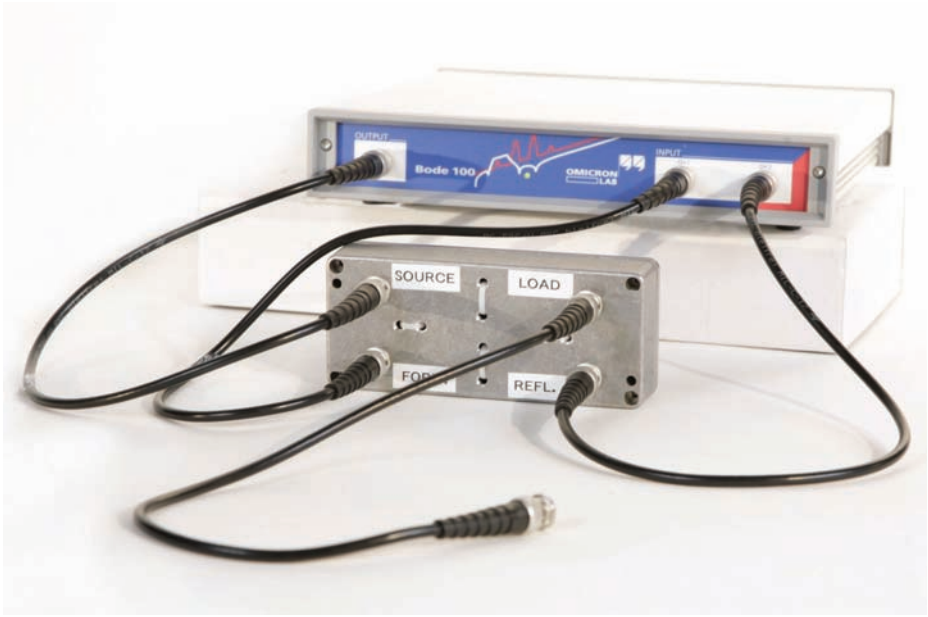
Hint: To match the impedance of the directional coupler, the input resistances of the channel 1 and channel 2 are set to 50 Ω.

5. Click the **Connection Setup** tab.



The connection diagram shows how to connect the DUT as well as the directional coupler to the *Bode 100*.

6. Connect the directional coupler to the *Bode 100* as shown.

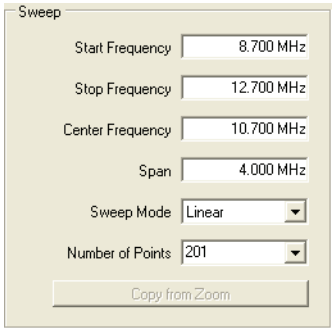


7. Click OK to close the **Configuration** window and to get back to the **Frequency Sweep (External Coupler)** mode window.

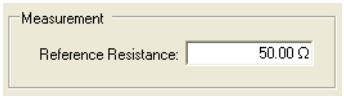
8. Set the sweep frequencies:

- Start frequency: 8.7 MHz
- Stop frequency: 12.7 MHz
- Number of points: 201

The other settings will be automatically calculated and the **Sweep** area of the **Frequency Sweep (External Coupler)** mode window should now look like below.



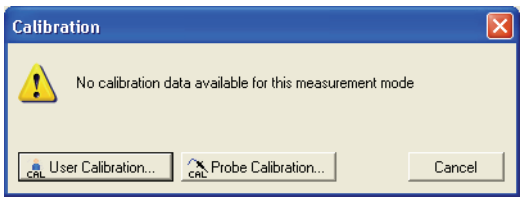
9. Set the reference resistance.
Default: 50 Ω



The reference resistance is used to calculate the reflection coefficient and the VSWR.

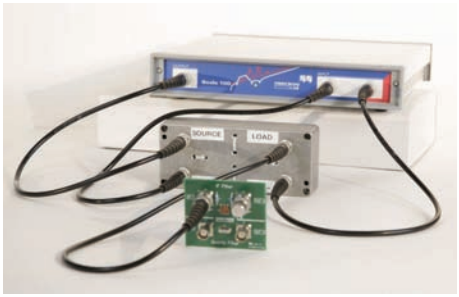
10. Calibrate the measurement setup as described in 7.6 "Calibration in the Frequency Sweep (External Coupler) Mode" on page 91.

Hint: Due to the strongly varying parameters of directional couplers a calibration is mandatory before performing a measurement. If you start a measurement in the **Frequency Sweep (External Coupler)** mode without calibration, the following dialog box appears.

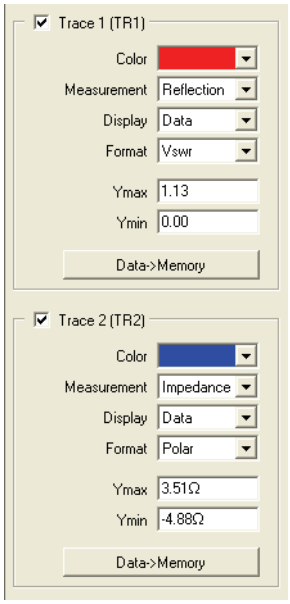


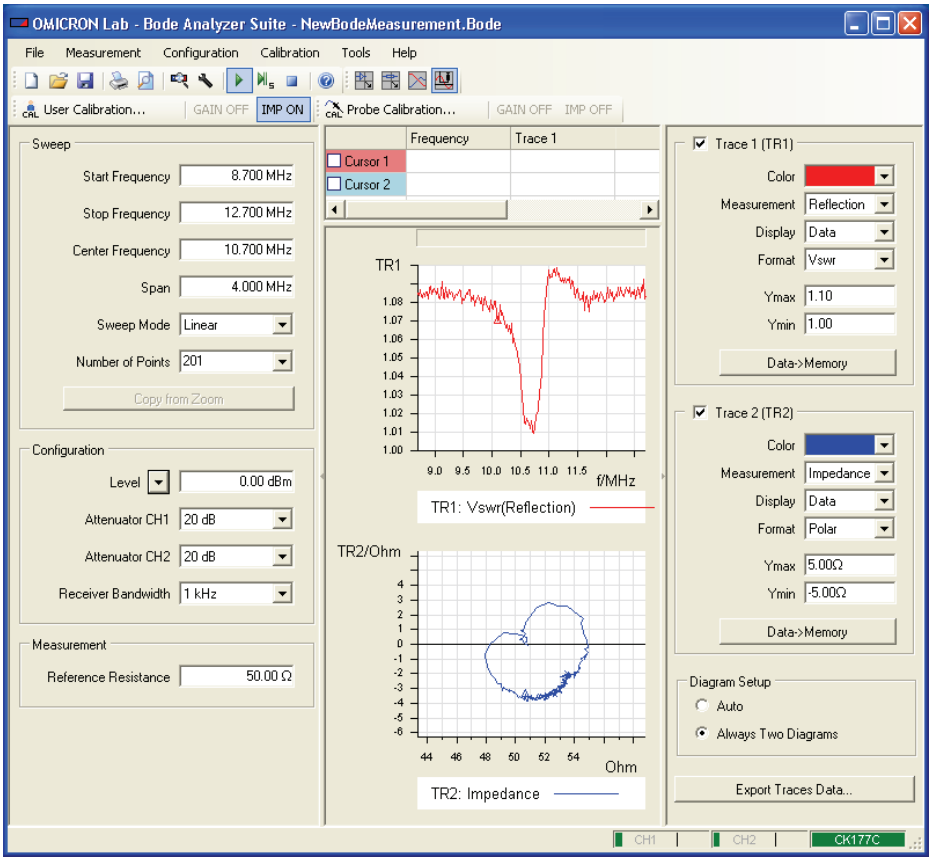
In this case, select the **User Calibration** or the **Probe Calibration**, and then proceed as described in 7.6 "Calibration in the Frequency Sweep (External Coupler) Mode" on page 91.

11. Connect the IF Filter to the *Bode 100* and the 50 Ω load to the output of the IF filter as shown below.



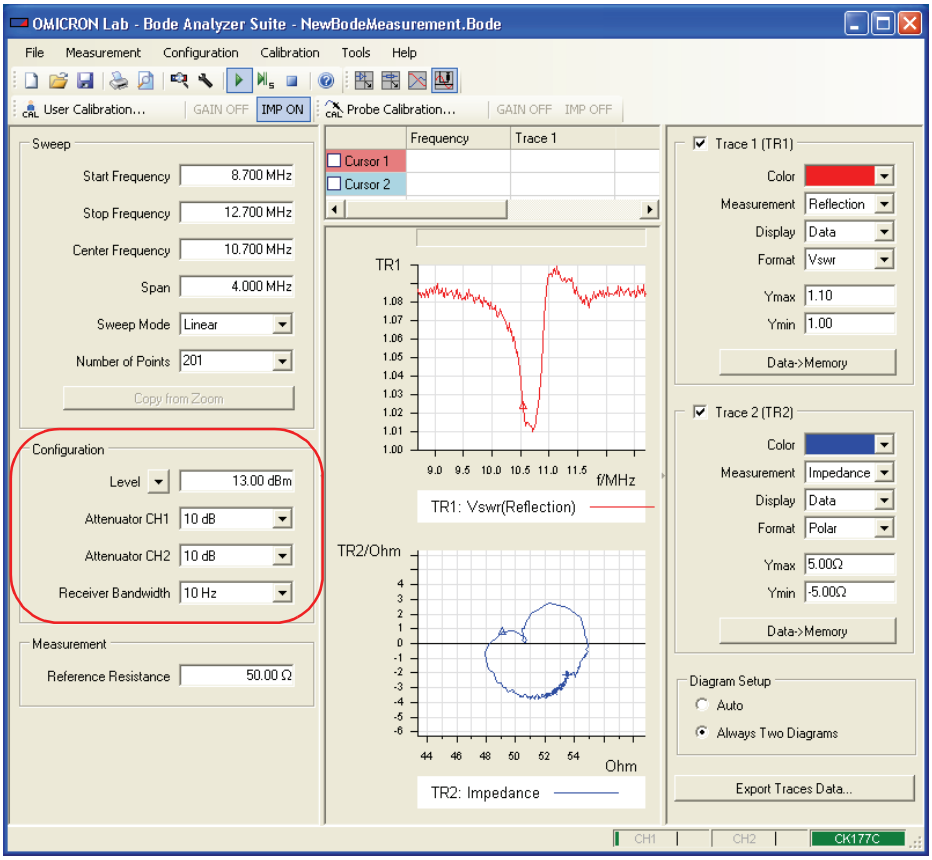
12. Activate both traces and set the parameters as shown below.



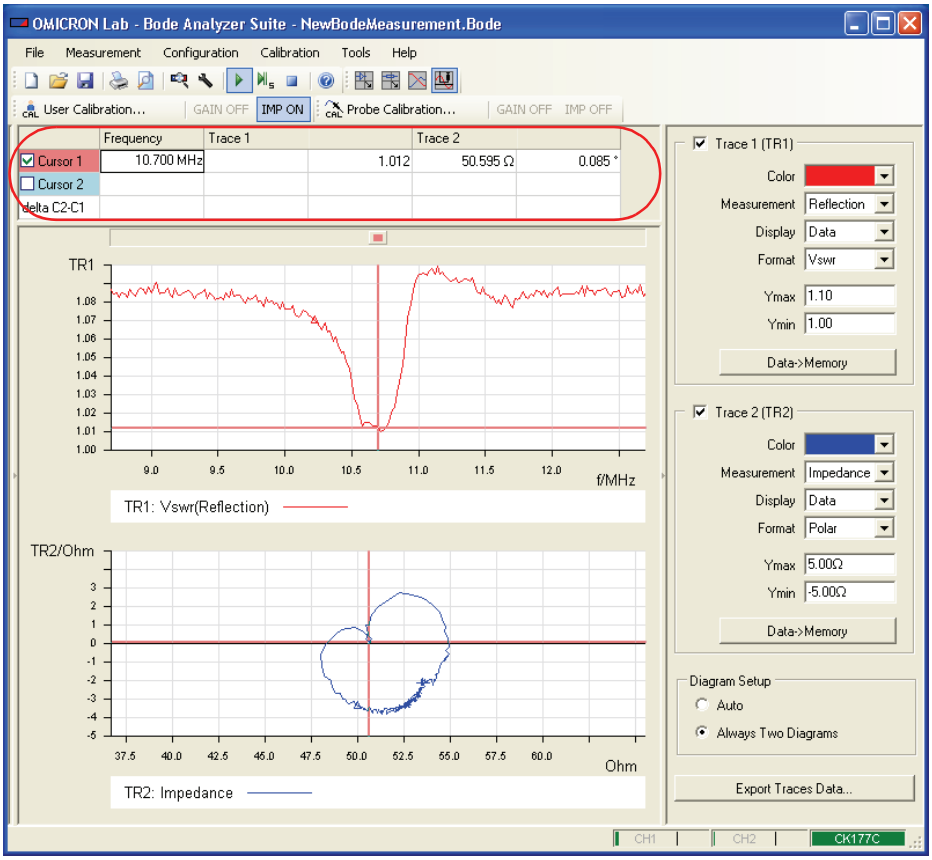


In the upper graph you see the reflection of the IF filter in VSWR format. Even outside its passband the VSWR of the filter is quite good – this indicates that the input impedance of the filter in the measured frequency range is very close to 50 Ω in general. The lower graphs shows the impedance of the IF filter in polar format, the so-called polar curve.

Hint: The effect of noise on the measurement results can be reduced by narrowing the receiver bandwidth, by using less attenuation in the input channels and by increasing the signal level of the *Bode 100* source output.



13. Select the **Cursor 1** check box to activate the cursor, and then set the cursor to the IF filter's center frequency of 10.7 MHz by entering 10.7 MHz in the respective box of the cursor spreadsheet.



Result: The VSWR of the IF filter at its center frequency is **1.012**. The impedance graph shows an impedance of 50.59 Ω and due to the very small positive phase shift a nearly pure resistive behavior.

Sometimes external couplers help to make a match and to enhance the power.

Congratulation! You learned how to use the **Frequency Sweep (External Coupler)** mode.

How to:

- Connect an external coupler
- Set configuration parameters like the input resistor and bandwidth
- Calibrate and compensate the connection system
- Display reflection in VSWR format
- Display impedance in polar format
- Remove the effect of noise

Go back to the **Frequency Sweep (External Coupler)** window in 6 "Frequency Sweep (External Coupler) Mode" on page 63 and try things out.

7 Calibrating the *Bode 100*

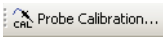
The *Bode 100* can compensate effects of the measurement setup like cables and probes. Further on the overall accuracy may be improved by calibrating the *Bode 100* (e.g. if the operating temperature is outside the range specified in 12.5 "Environmental Requirements" on page 137).

7.1 Calibration Methods

The *Bode 100* supports two calibration methods: the **Probe Calibration** optimized for measurements which require frequent changes of measurement settings and the **User Calibration** for most accurate results.

Note: During startup, the *Bode 100* executes an **Internal Calibration** algorithm. During this calibration, internal attenuators and amplifiers are measured and calibrated.

7.1.1 Probe Calibration



The **Probe Calibration** of the *Bode 100* allows you to change several measurement parameters without the need of recalibration. During the **Probe Calibration**, calibration factors are determined at factory defined frequencies within the complete frequency range. The calibration factors for the frequency points used by the current measurement settings are then obtained by interpolation.

Hint: The **Probe Calibration** compensates effects of cables and broad-band probes. If you want to compensate frequency selective probes or if your cable length exceeds 10 m it is recommended to use the **User Calibration** (see 7.1.2 "User Calibration" on page 76).

The **Probe Calibration** allows **changing** the following parameters **without the need of recalibrating** the *Bode 100*:

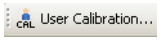
- Frequency values
- Sweep mode (linear/logarithmic)
- Number of measurement points (in the **Frequency Sweep** modes)
- Source level
- Attenuator 1 and attenuator 2
- Receiver bandwidth
- Zoom **with & without** the **Copy from Zoom** function (see "Copy from Zoom" on page 107)

The **Probe Calibration** will be **switched off automatically** if the following parameters are changed:

- Reference mode (internal/external reference)
- Conversion ratio of external probes (see 9.4 "Using Probes" on page 125)
- Input resistance of channel 1 and/or channel 2 (low/high impedance)

Hint: Use the **Probe Calibration** if measurement parameters have to be changed often during the measurements. You will save time because you do not need to recalibrate the *Bode 100* each time you changed the parameters.

7.1.2 User Calibration



The **User Calibration** is the most accurate calibration method available with the *Bode 100*. The **User Calibration** is performed directly at the exact measurement frequencies. In the **Gain/Phase** and **Impedance/Reflection** measurement modes, the *Bode 100* is calibrated at the source frequency. In the **Frequency Sweep** modes, the calibration is performed at the exact frequencies specified by the measurement points.

The **User Calibration** allows **changing** the following parameters **without the need of recalibrating** the *Bode 100*:

- Source level
- Attenuator 1 and attenuator 2
- Receiver bandwidth
- Zoom **without** the **Copy from Zoom** function (see "Copy from Zoom" on page 107)

The **User Calibration** will be **switched off automatically** if one of the following parameters is changed:

- Frequency values
- Sweep mode (linear/logarithmic)
- Number of measurement points (in the **Frequency Sweep** modes)
- Reference mode (internal/external reference)
- Conversion ratio of external probes (see 9.4 "Using Probes" on page 125)
- Input resistance of channel 1 and/or channel 2 (low/high impedance)
- Zoom **with** the **Copy from Zoom** function (see "Copy from Zoom" on page 107)

Hint: Use the **User Calibration** for the highest accuracy of measurement results or if you want to compensate for highly frequency selective components in your measurement setup such as narrow-band measurement probes.

7.1.3 Hierarchy of Calibration Methods

The following table gives an overview of the *Bode 100* calibration methods.

Table 7-1: Calibration methods

Measurement Mode	User Calibration	Probe Calibration
Gain/Phase	Calibrates at only one frequency (measurement frequency)	Calibrates the complete frequency range. Calibration factor for the measurement frequency is calculated by linear interpolation.
Impedance/Reflection		
Frequency Sweep	Calibrates at the exact frequency points used for the sweep	Calibrates the complete frequency range. Calibration factors for the measurement frequencies are calculated by linear interpolation.
Frequency Sweep (External Coupler)		

You can activate the **User Calibration** and the **Probe Calibration** at the same time as shown below.

Figure 7-1: Activating **User Calibration** and **Probe Calibration**

If both the **User Calibration** and the **Probe Calibration** are activated, the more accurate **User Calibration** is used. If measurement parameters are changed and the **User Calibration** becomes void the *Bode 100* switches automatically to the **Probe Calibration**; the **User Calibration** remains switched off until the *Bode 100* is recalibrated.

7.2 Calibration in the Gain/Phase Mode (Internal Reference Connection)

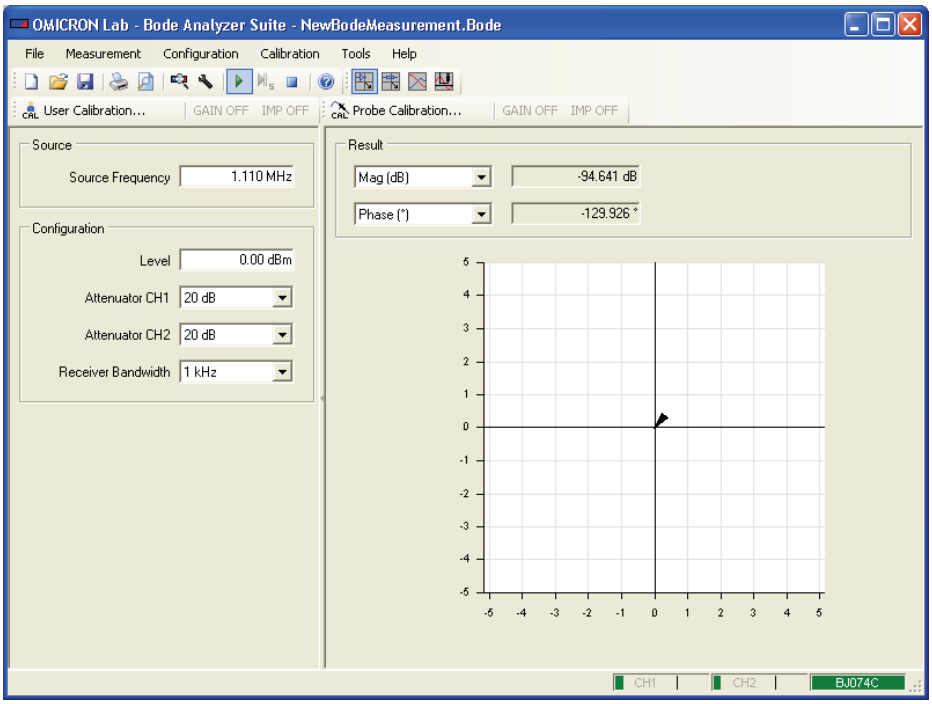
For calibrating the *Bode 100* in the **Gain/Phase** mode you find a practical example in 3.3 "Example: Gain/Phase Measurement" on page 24.

Note: The **Probe Calibration** is performed in the same way as the **User Calibration**.

7.3 Calibration in the Gain/Phase Mode (External Reference Connection – CH1)

To compensate for the cable and connection setup effects in the **Gain/Phase** mode, proceed as follows:

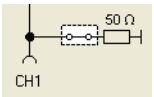
1. Connect the *Bode 100* and start the *Bode Analyzer Suite*.
   Select the **Gain/Phase** mode.

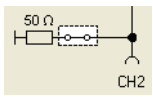


2. Click the **Device Configuration** toolbar button to open the **Configuration** window.
   In the **Configuration** window, set the parameters for your measurement. In our example we have chosen the following settings.

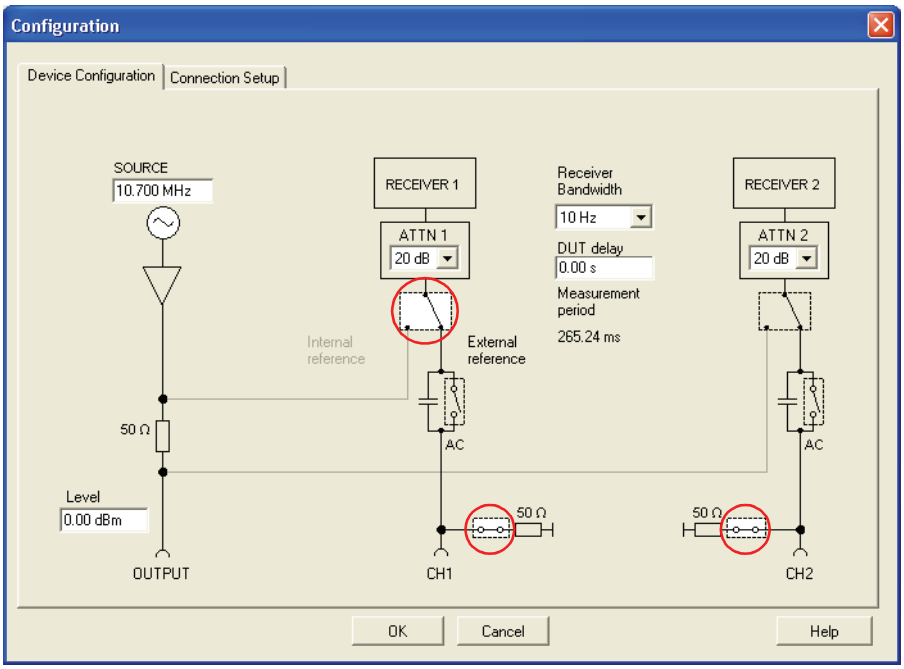
3. Set:

- External reference CH1 (Click the switch symbol .)
- CH1 and CH2: 50 Ω (Click the switch symbols.)

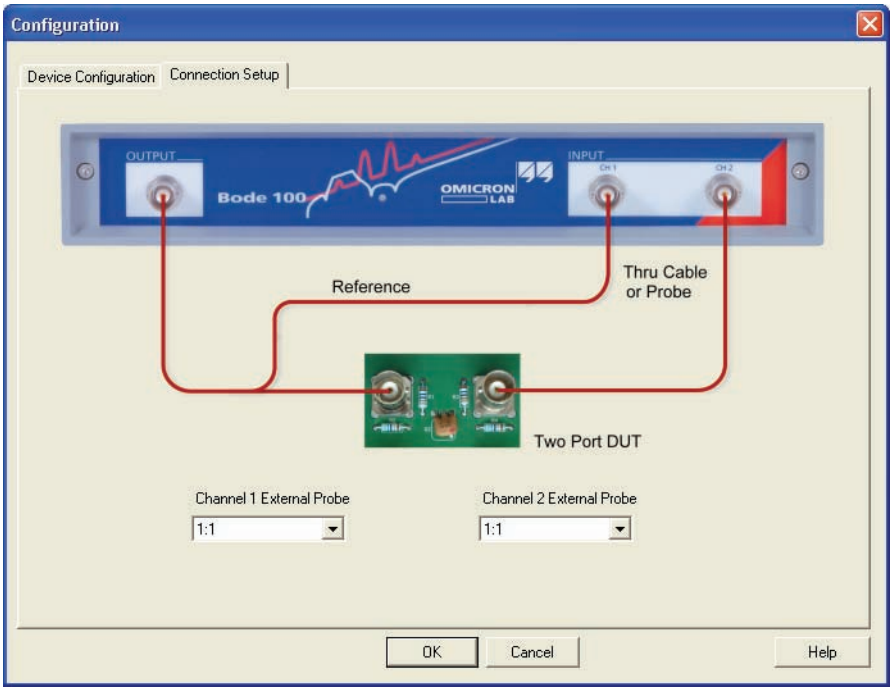




- SOURCE: 10.7 MHz
- Receiver bandwidth: 10 Hz
- ATTN 1: 20 dB
- ATTN 2: 20 dB
- Level: 0 dBm



4. Click the **Connection Setup** tab.

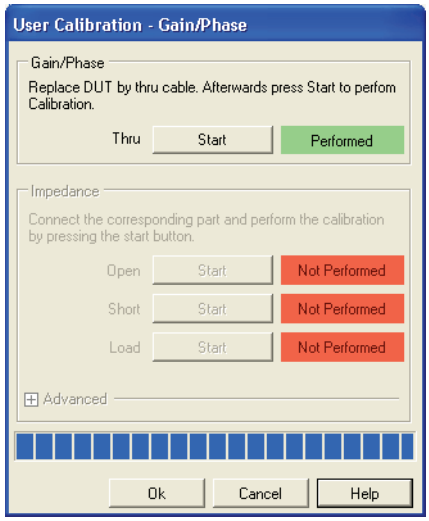


The connection diagram shows how to connect the DUT to the *Bode 100*.

5. Connect the cables you want to use for the measurement as shown below.

6. Click OK to close the **Configuration** window.
7. Choose either the **Probe Calibration** or the **User Calibration** and click the respective toolbar button.

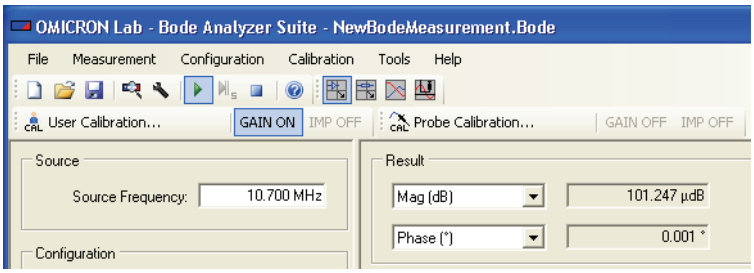
8. In the respective calibration window, click the **Start** button next to **Thru** to calibrate the *Bode 100*.



Note: In the **Gain/Phase** mode, no **Impedance** calibration is possible.

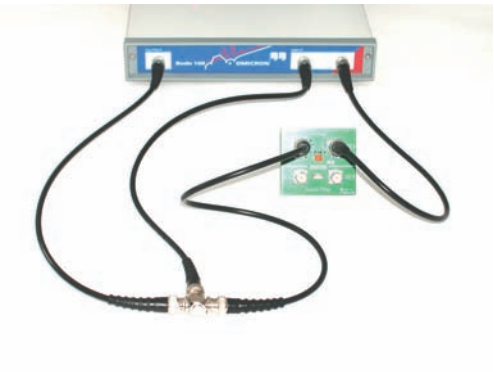
The **Gain/Phase** mode is now calibrated for the current specific measurement setup. Refer to 7.1 "Calibration Methods" on page 75 to learn in which cases you have to repeat the calibration if a parameter is changed.

9. Click OK.



In our case we read 101 µdB (0.000101 dB) and 0.001º. Because we are close to zero your results may differ from this example. Nevertheless the displayed values should be very small.

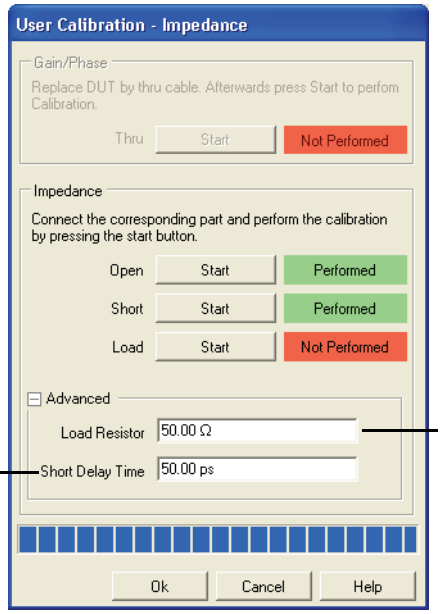
10. The calibration is done and you can replace the BNC straight adapter with your DUT as shown below.



7.4 Calibration in the Impedance/Reflection Mode

By calibrating the *Bode 100* you can remove the effects of the connection setup on the accuracy of the measurement results in the **Impedance/Reflection** mode. Without calibration the reference plane of the impedance measurements is at the BNC connector of the *Bode 100* source output. Therefore if a DUT is connected through a cable, the measured impedance is the combination of the cable's impedance and the DUT's impedance. By calibrating the *Bode 100* you can move the reference plane for the impedance measurement to the end of the connection cable and fully remove the influence of the cable.

In the **Impedance** area of the calibration window, you can set the resistance of the load resistor and the short delay time as shown below.



Enter the delay time of the short circuit used for calibration
Factory setting valid for the short circuit delivered with the *Bode 100*: 50 ps

Enter the exact resistance of the load used for calibration
Factory setting: 50 Ω

Hint: If the entered values of the load resistor and/or the short delay time differ from the factory settings a yellow warning symbol appears after the **Advanced** area has been collapsed.

Example: Measure the input impedance of the IF filter at the BNC connector of the PCB (and not the impedance at the input of the cable connecting the filter).

Expected example duration: 20 minutes.

In this example you will learn step by step how to use the calibration of the *Bode 100* in the **Impedance/Reflection** mode.

How to:

- Eliminate the effect of the cable
- Connect the cable in the open, short and load condition
- Connect the DUT

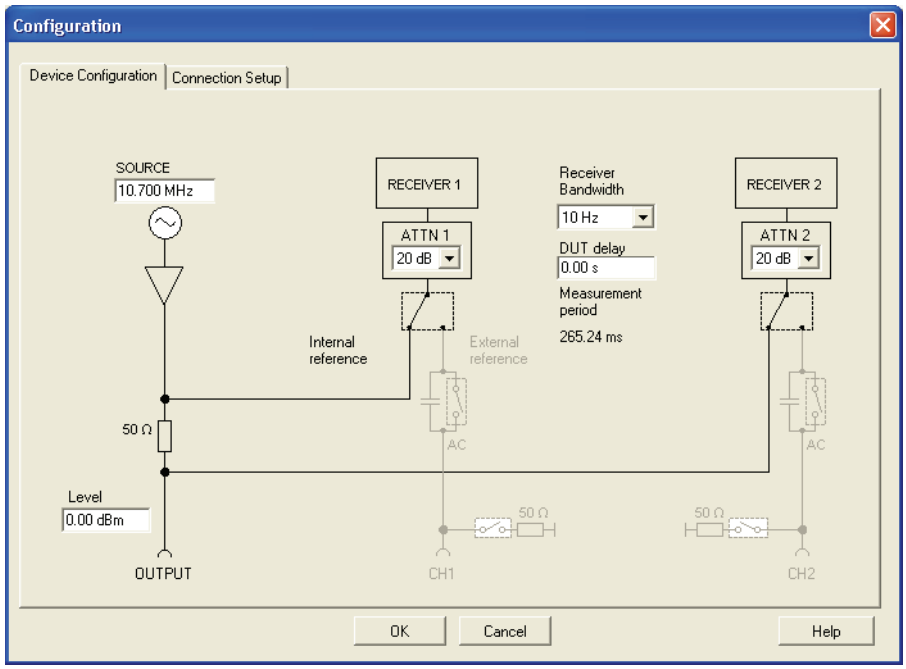
Questions:

- What is the real part of the impedance in Ω?
- What is the reflection coefficient in dB?

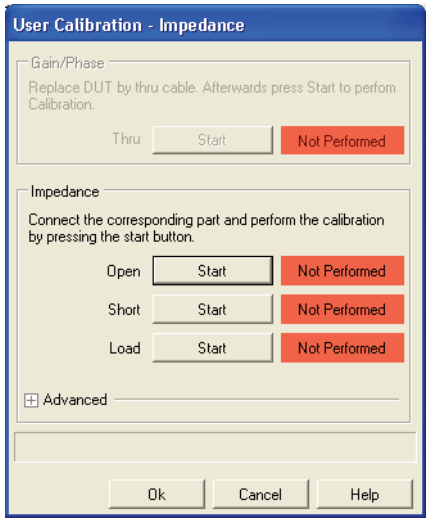
To find out the answers, proceed as follows:

1. Click the **Impedance/Reflection** toolbar button to switch to the **Impedance/Reflection** mode.
2. Click the **Device Configuration** toolbar button to open the **Configuration** window.
3. Because we want to test the 10.7 MHz IF filter, set:

- SOURCE: 10.7 MHz
- Receiver bandwidth: 10 Hz
- Level: 0 dB



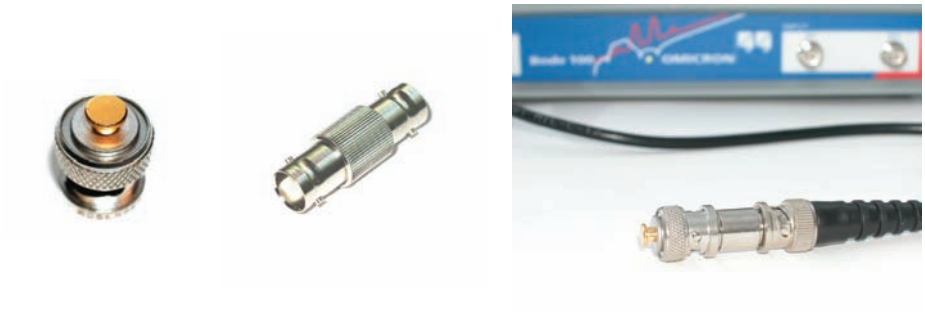
4. Click OK.
5. Choose either the **Probe Calibration** or the **User Calibration** and click the respective toolbar button.



6. Connect the cable you want to use for the measurement to the OUTPUT connector of the *Bode 100*. Plug the BNC straight adapter on the other end of the cable to have the same reference plane for calibration.

7. Click the **Start** button next to **Open** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

8. Plug the BNC short circuit on the straight adapter connected to the cable.



Hint: If you use a short circuit other than the one delivered with your *Bode 100* you can enter the short delay by clicking the + symbol next to **Advanced** and typing the short delay time.

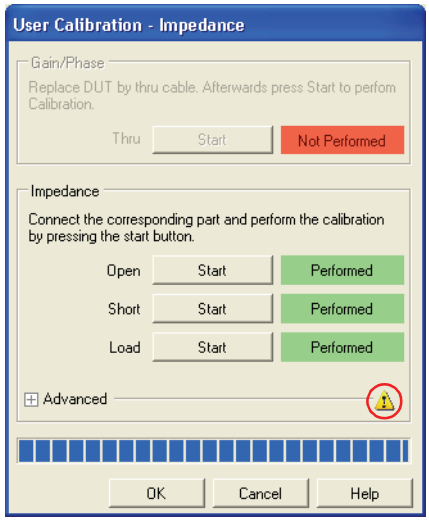
9. Click the **Start** button next to **Short** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

10. Replace the BNC short circuit with the BNC 50 Ω load.

11. For very accurate measurements or if you use a load resistor different from 50 Ω, click the + symbol next to **Advanced**, and then enter the exact resistance of the load resistor.

12. Click the **Start** button next to **Load** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

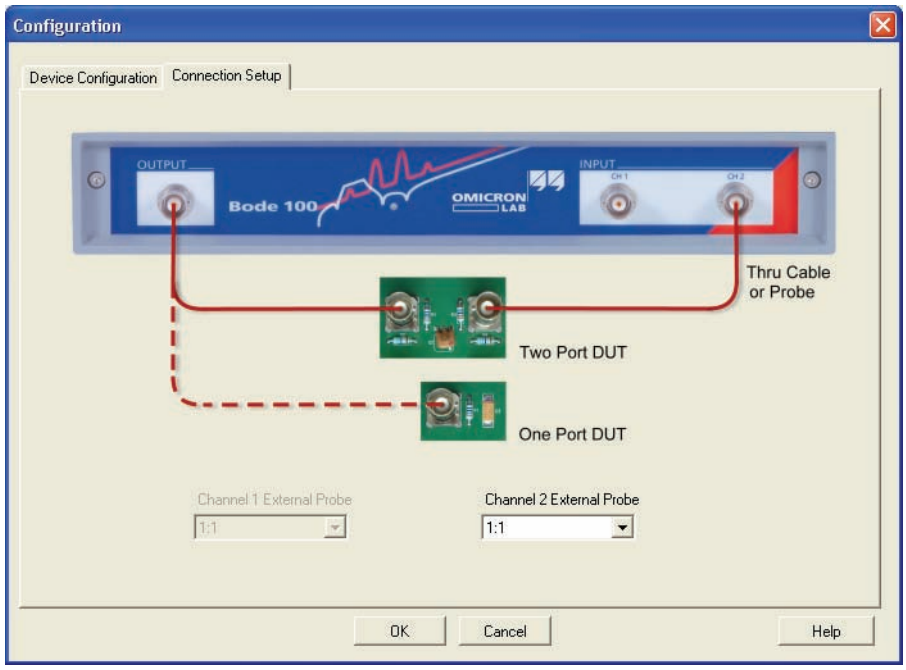
13. After the calibration has been finished, the calibration window looks like shown below.



Hint: If the entered values of the load resistor and/or the short delay time differ from the factory settings a yellow warning symbol appears after the **Advanced** area has been collapsed.

14. Click OK. You have done the **Impedance** calibration.

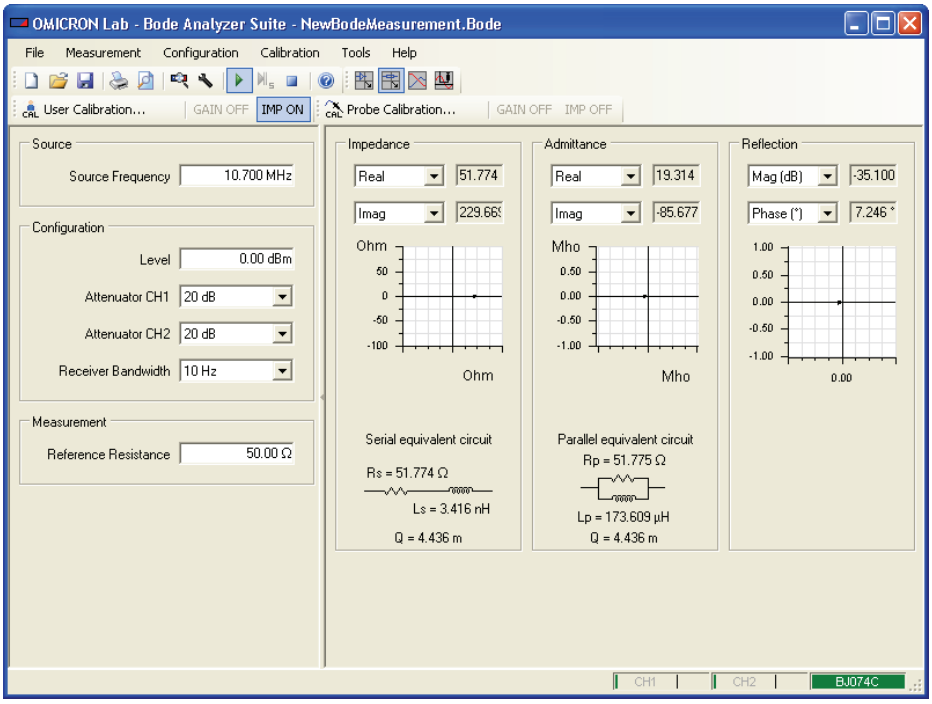
15. Open the **Configuration** window by clicking the **Device Configuration** toolbar button to see how to connect your DUT to the *Bode 100*.



16. Connect the test object.

Note: The IF filter is a two-port device. To ensure that the impedance of the filter is measured correctly, its output must be terminated. For measuring a one-port device like a capacitor or an inductor, no termination resistor is needed.

17.Read the results.



Answers:

- The real part of the impedance is 51.8 Ω.
- The magnitude of the reflection coefficient is –35.1 dB.

Your results may differ because every IF filter and measurement setup is slightly different.

Congratulation! You learned the calibration of the *Bode 100* in the **Impedance/Reflection** mode.

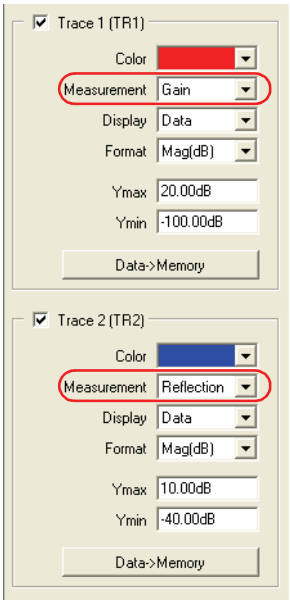
How to:

- Eliminate the effect of the cable
- Connect the cable in the open, short and load condition
- Connect the DUT

I had my first cable problem when I was born but luckily the midwife solved that problem.

7.5 Calibration in the Frequency Sweep Mode

In the **Frequency Sweep** mode, you can perform **Gain/Phase** and **Impedance/Reflection** measurements. Therefore both the **Gain/Phase** and the **Impedance** calibration are available. The actually performed measurements depend on the measurement type assigned to **Trace 1** and **Trace 2**.



To perform the **Gain/Phase** calibration in the **Frequency Sweep** mode, proceed as described in 3.3 "Example: Gain/Phase Measurement" on page 24. For the **Impedance** calibration, see 5.2 "Impedance Calibration" on page 57.

Hints:

The calibration time for the **User Calibration** depends on the number of measurement points and the selected receiver bandwidth.

The calibration time required for the **Probe Calibration** depends only on the selected receiver bandwidth.

When working with the *Bode 100* at frequencies below 10 Hz, the calibration can be quite long.

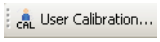
7.6 Calibration in the Frequency Sweep (External Coupler) Mode

By calibrating the *Bode 100* in the **Frequency Sweep (External Coupler)** mode you remove the effects of the connection setup including the external coupler and, if used, the amplifier on the accuracy of the measurement results. Due to the strongly varying parameters of directional couplers a calibration is mandatory before performing a measurement.

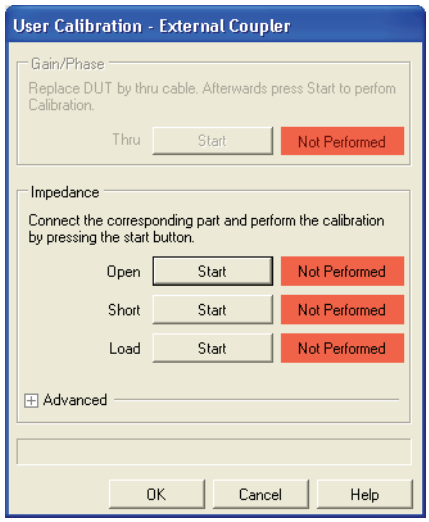
In the **Frequency Sweep (External Coupler)** mode, you can perform only **Impedance/Reflection** measurements. Therefore only the **Impedance** calibration is available in this mode.

Hint: Some directional couplers show nonlinear behavior at the edges of their passband. If your measurement frequency range is close to such nonlinearities, we recommend to use the **User Calibration** to remove the nonlinear effects.

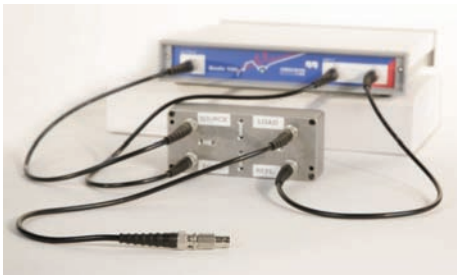
To calibrate the *Bode 100* in the **Frequency Sweep (External Coupler)** mode:

1. Click the **Frequency Sweep (External Coupler)** toolbar button to switch to the **Frequency Sweep (External Coupler)** mode.
2. Click the **User Calibration** toolbar button 

to open the calibration window.



3. Plug the BNC straight adapter on the end of the cable.

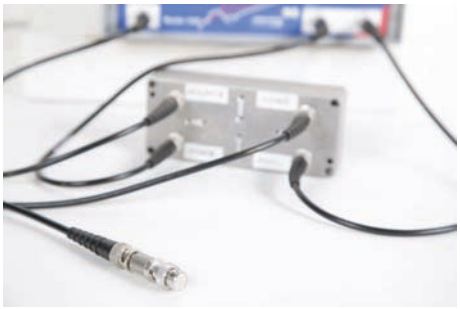


4. Click the **Start** button next to **Open** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

5. Plug the BNC short circuit on the straight adapter connected to the cable.

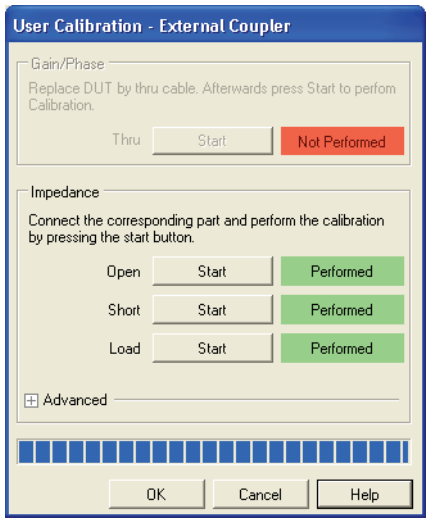
6. Click the + symbol next to **Advanced**, and then enter the short delay time (only if you use a short circuit other than the one delivered with your *Bode 100*).
7. Click the **Start** button next to **Short** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

8. Replace the BNC short circuit with the BNC 50 Ω load.



9. For very accurate measurements or if you use a load resistor different from 50 Ω, enter the exact resistance of the load resistor in the respective box in the **Advanced** area of the calibration window.
10. Click the **Start** button next to **Load** in the **Impedance** area of the calibration window. After the calibration has been finished, the field on the right displays **Performed** on green background.

11. After the calibration has been finished, the calibration window looks like shown below.



Hint: A yellow warning symbol displayed close to **Advanced** indicates that the short delay and/or the load resistance entered in the **Advanced** area differ from the factory settings.

12. Click OK. You have done the **Impedance** calibration in the **Frequency Sweep (External Coupler)** mode.

8 Common Functions

In this section you can find the *Bode Analyzer Suite* basics. The section provides an overview of the toolbars, menus and commands common to all measurement modes. Further on, this section explains how to change the measurement range, how to export the data and how to store and load configuration files.

8.1 Toolbars, Menus and Commands

Figure 8-1:
Toolbar

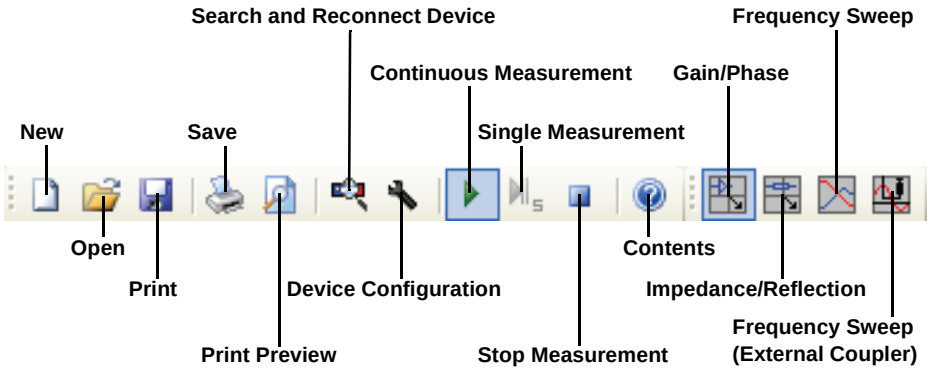


Figure 8-2:
Calibration toolbar

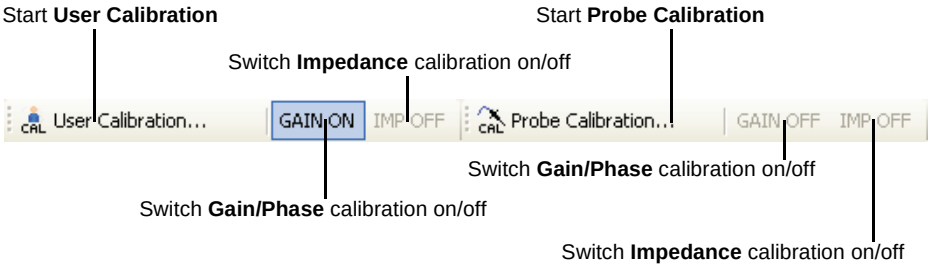


Table 8-1:
Menus and commands

Menu	Command	Description
File	**New**	Opens the NewBodeMeasurement.Bode file containing default settings.
	Open	Opens a .Bode file containing saved settings and measurement data.
	Save	Saves the device configuration, measurement settings, calibration and measurement data and the graphical display settings.
	Save As	
	Print	Print a report containing the diagram, measurement results, and device configuration data.
	Print Preview	Previews the print report.
	Exit	Enables you to exit the *Bode Analyzer Suite*.
Measurement	**Gain/Phase**	Selects the **Gain/Phase** measurement mode.
	Impedance/Reflection	Selects the **Impedance/Reflection** measurement mode.
	Frequency Sweep	Selects the **Frequency Sweep** measurement mode.
	Frequency Sweep (External Coupler)	Selects the **Frequency Sweep (External Coupler)** measurement mode.
	Continuous Measurement	Starts continuous measurements.
	Single Measurement	Starts a single frequency sweep measurement.[1]
	Stop Measurement	Stops measurement. The last result remains displayed.

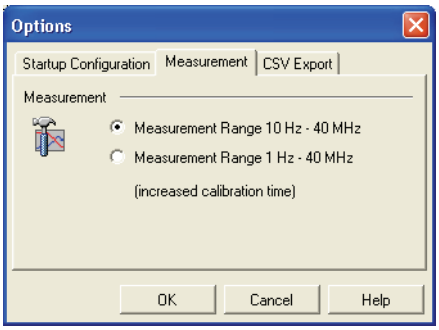
1. Only available in the **Frequency Sweep** modes

Menu	Command	Description
Configuration	**Device Configuration**	Enables you to configure the *Bode 100*.
	Connection Setup	Shows the connection of the DUT to the *Bode 100*.
	Search and Reconnect Device	Reconnects the *Bode 100* with the computer.
Calibration	**User Calibration**	Starts the **User Calibration** (see 7 "Calibrating the Bode 100" on page 75).
	Probe Calibration	Starts the **Probe Calibration** (see 7 "Calibrating the Bode 100" on page 75).
Tools	**Options**	Enables you to set the startup configuration (see 8.3.1 "Loading and Saving the Equipment Configuration" on page 98), to select the measurement range (see 8.2 "Setting the Measurement Range" on page 98) and to set the CSV export options (see 8.3 "File Operations" on page 98).
Help	**Contents**	Starts the *Bode Analyzer Suite* Help.
	Bode 100 Web site	Opens the OMICRON Lab Web site www.omicron-lab.com.
	About	Displays the *Bode Analyzer Suite* version.

8.2 Setting the Measurement Range

With the *Bode 100* you can perform measurements within 10 Hz…40 MHz (default frequency range) and 1 Hz…40 MHz (extended frequency range). To select the measurement range, click **Options** on the **Tools** menu, click the **Measurement** tab, and then select the frequency range for your measurement.

Figure 8-3: Setting the measurement range



8.3 File Operations

The *Bode 100* supports the following file operations.

8.3.1 Loading and Saving the Equipment Configuration

You can store all settings of the *Bode 100* including the device configuration, measurement settings, calibration and measurement data and the graphical display settings by clicking the **Save** toolbar button (see Table 8-1: "Menus and commands" on page 96).

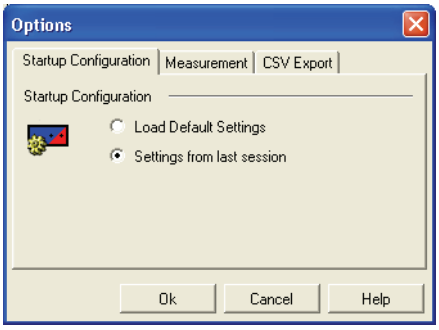
Hint: This functionality allows you to store multiple equipment configurations for repetitive measurement tasks. With the equipment configurations stored, you can load the respective files for each measurement instead of setting the *Bode 100* manually.

A saved file containing the *Bode 100* settings has the .Bode extension. The file is stored in XML format and can be viewed with standard Web browsers or a simple text editor tool.

After loading a .Bode file the stored measurement data is displayed. To preserve these values, the measurement is held (the **Stop Measurement** toolbar button is activated). In this state you can change display options and use cursors to read measurement data. To continue with your measurement, click the **Continuous Measurement** toolbar button .

Hint: To ensure that the *Bode 100* starts with the same configuration as in your last session, click **Options** on the **Tools** menu, click the **Startup Configuration** tab, and then select **Settings from last session**.

Figure 8-4:
Setting the startup configuration

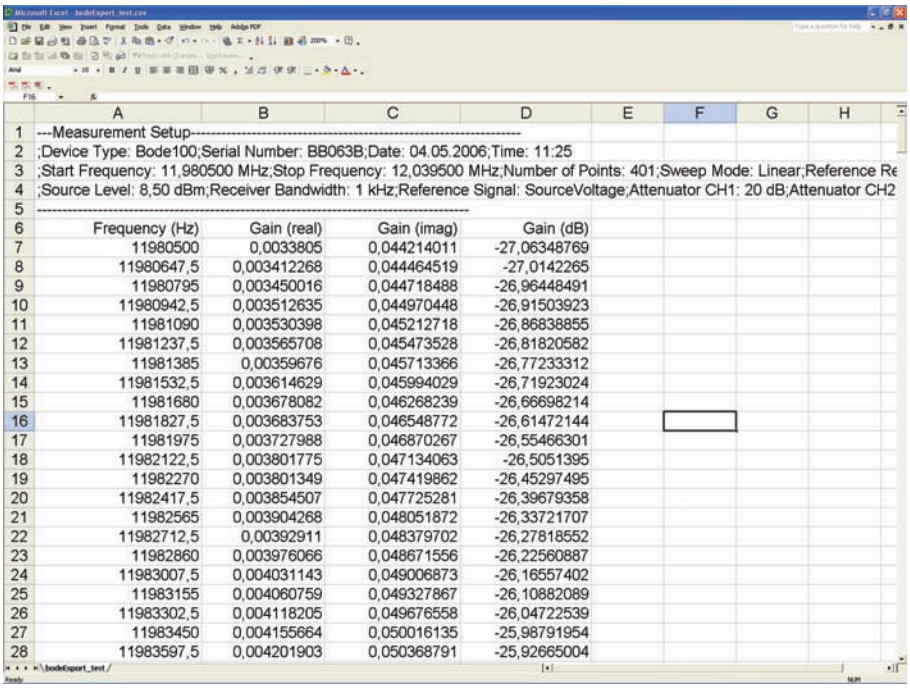


8.3.2 Exporting Measurement Data

In the **Frequency Sweep** and **Frequency Sweep (External Coupler)** modes, you can export the measurement data by clicking the Export Traces Data... button. In addition to the trace (measurement) data, all equipment settings are exported into a comma separated .csv file. This file format can be easily processed by standard spread-sheet analysis tools such as Excel®. The .csv file always contains the real and the imaginary part of the measured parameter (e.g. gain). Additionally, the measurement data in the selected output format is included.

Hint: If you have selected **Settings from last session** the calibration settings of you last session are NOT loaded. This is done on purpose since your measurement setup might have changed since you last used the *Bode 100*. If you want to load measurement settings including the calibration data, use the *Bode 100* file functions (see 8.3.1 "Loading and Saving the Equipment Configuration" on page 98). However, we recommend to recalibrate the *Bode 100* each time you start a new work session.

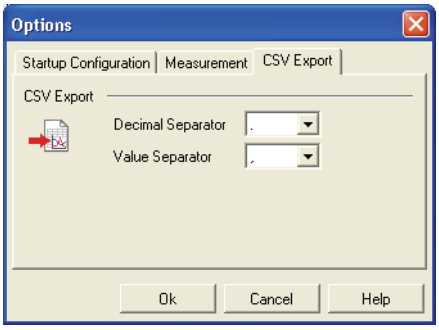
Figure 8-5:
Displayed CSV file data



	A	B	C	D	E	F	G	H
1	---Measurement Setup----------							
2	;Device Type: Bode100;Serial Number: BB063B;Date: 04.05.2006;Time: 11:25							
3	;Start Frequency: 11,980500 MHz;Stop Frequency: 12,039500 MHz;Number of Points: 401;Sweep Mode: Linear;Reference Re							
4	;Source Level: 8,50 dBm;Receiver Bandwidth: 1 kHz;Reference Signal: SourceVoltage;Attenuator CH1: 20 dB;Attenuator CH2							
5	----------							
6		Frequency (Hz)	Gain (real)	Gain (imag)	Gain (dB)			
7		11980500	0,0033805	0,044214011	-27,06348769			
8		11980647,5	0,003412268	0,044464519	-27,0142265			
9		11980795	0,003450016	0,044718488	-26,96448491			
10		11980942,5	0,003512635	0,044970448	-26,91503923			
11		11981090	0,003530398	0,045212718	-26,86838855			
12		11981237,5	0,003565708	0,045473528	-26,81820582			
13		11981385	0,00359676	0,045713366	-26,77233312			
14		11981532,5	0,003614629	0,045994029	-26,71923024			
15		11981680	0,003678082	0,046268239	-26,66698214			
16		11981827,5	0,003683753	0,046548772	-26,61472144			
17		11981975	0,003727988	0,046870267	-26,55466301			
18		11982122,5	0,003801775	0,047134063	-26,5051395			
19		11982270	0,003801349	0,047419862	-26,45297495			
20		11982417,5	0,003854507	0,047725281	-26,39679358			
21		11982565	0,003904268	0,048051872	-26,33721707			
22		11982712,5	0,00392911	0,048379702	-26,27818552			
23		11982860	0,003976066	0,048671556	-26,22560887			
24		11983007,5	0,004031143	0,049006873	-26,16557402			
25		11983155	0,004060759	0,049327867	-26,10882089			
26		11983302,5	0,004118205	0,049676558	-26,04722539			
27		11983450	0,004155664	0,050016135	-25,98791954			
28		11983597,5	0,004201903	0,050368791	-25,92665004			

To adapt the .csv file to your requirements, you can choose between different decimal and value separators. To select the separators you want to use, click **Options** on the **Tools** menu, click the **CSV Export** tab, and then select the decimal and value separators.

Figure 8-6:
Selecting the separators



9 Advanced Functions

The *Bode 100* provides additional features extending the *Bode Analyzer Suite* functionality described in sections 3 to 8 of this User Manual. This section describes these advanced functions which will make your daily measurement tasks with the *Bode 100* even easier.

9.1 Advanced Display Options

In all measurement modes, the *Bode Analyzer Suite* provides several possibilities to visualize the measurement results according to your needs. You can control these advanced display options through the shortcut menus and/or buttons in the main window.

9.1.1 Gain/Phase and Impedance/Reflection Mode

The shortcut menu in the **Gain/Phase** and **Impedance/Reflection** mode is shown below. To open the shortcut menu, right-click a diagram in the graphical display.

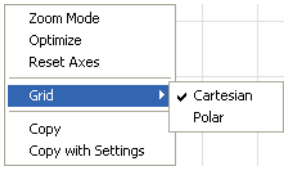


Figure 9-1: **Gain/Phase** and **Impedance/Reflection** mode shortcut menu

Optimize

The **Optimize** command allows you to optimize the diagram by scaling both axes so that you can see the complete measurement result in the highest possible resolution.

Figure 9-2:
Diagram with default settings

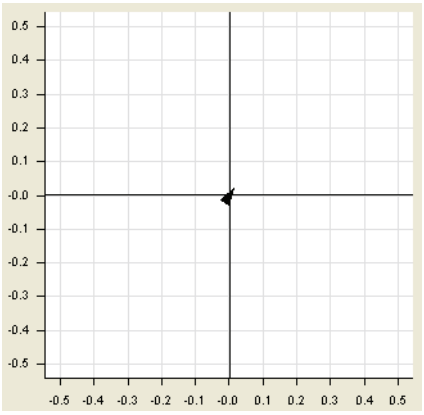
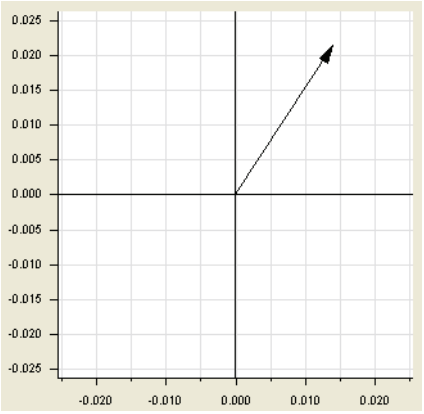


Figure 9-3:
Diagram after applying **Optimize**



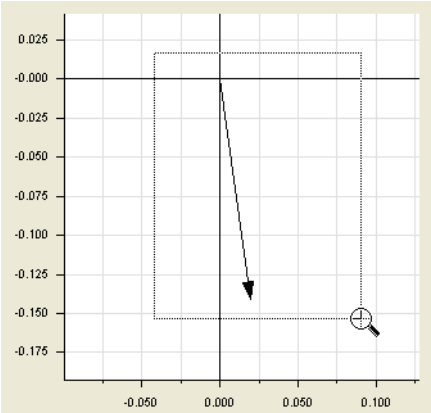
Reset Axes

The **Reset Axes** command resets both axes of the diagram to the default values.

Zoom Mode

After clicking **Zoom Mode**, the pointer changes to a magnifying glass when you move it over the diagram. Press and hold the left mouse button to select the zoom area. After releasing the left mouse button, the diagram is rescaled to display the zoomed area.

Figure 9-4:
Selecting zoom area



To switch off the zoom mode, right-click in the diagram, and then click **Zoom Mode** to cancel the selection.

To zoom out, right-click in the diagram, and then click **Reset Axes**. To optimize the graphical display, right-click in the diagram, and then click **Optimize**.

Copy

By clicking **Copy** you copy the complete diagram to the clipboard. Thereafter you can insert the diagram into all Windows® software applications which support the insertion of graphical clipboard content.

Copy with Settings

By clicking **Copy with Settings** you copy the complete diagram as well as all relevant equipment settings to the clipboard. From there you can insert the data into all Windows® software applications which support the insertion of graphical clipboard content. Depending on the chosen Windows® application, the clipboard content is inserted as a graphic (e.g. Microsoft Paint), an editable text (e.g. Microsoft Notepad) or a graphic plus the settings in editable text format (Microsoft Word).

9.1.2 Frequency Sweep and Frequency Sweep (External Coupler) Mode

The shortcut menu in the **Frequency Sweep** and **Frequency Sweep (External Coupler)** modes is shown below. To open the shortcut menu, right-click the diagram in the graphical display

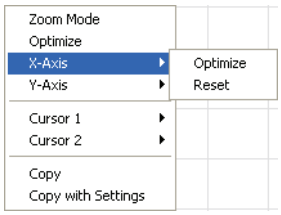


Figure 9-5: **Frequency Sweep** and **Frequency Sweep (External Coupler)** mode shortcut menu

For the **Reset**, **Optimize**, **Copy** and **Copy with Settings** commands, see 9.1.1 "Gain/Phase and Impedance/Reflection Mode" on page 101.

Zoom Mode

By using the **Zoom Mode** command, you can select a zoom area for an in-depth display of a part of the diagram. The zoom function is a nice way to inspect particular parts of the measurement curve without having to change the measurement parameters.

Figure 9-6:
Selecting the zoom area

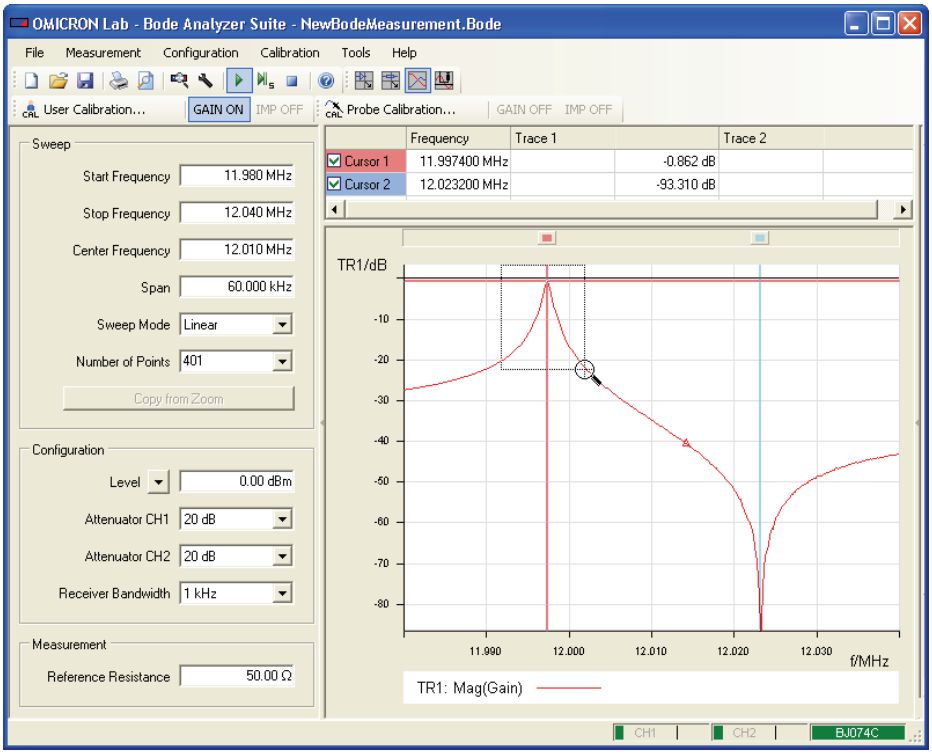
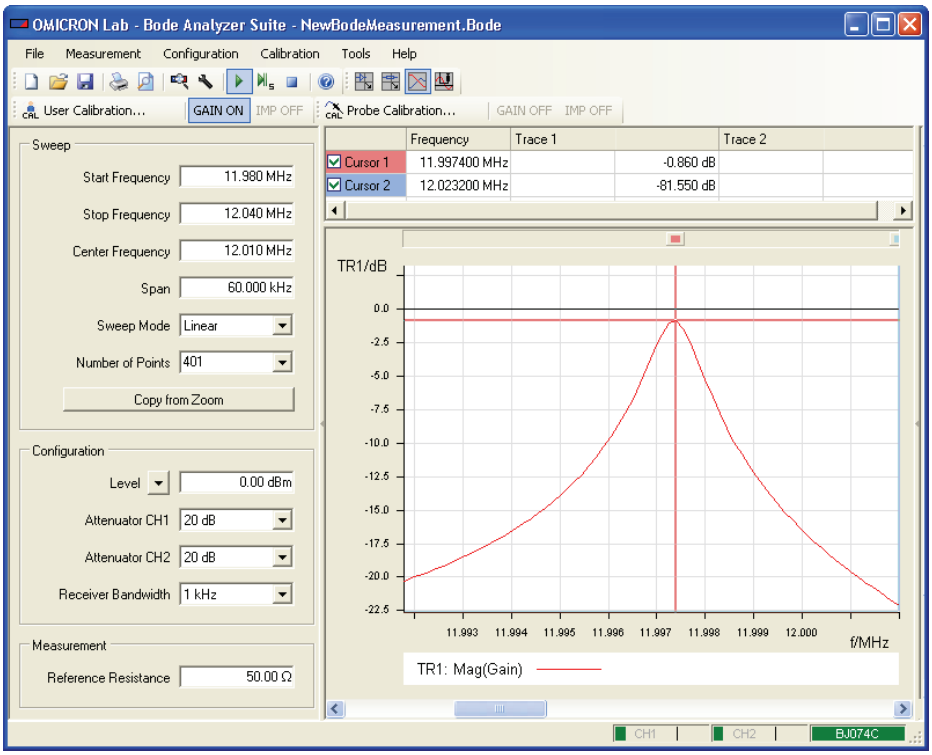


Figure 9-7: Displaying the zoom area



In the **Zoom Mode**, the measurement is still performed in the whole frequency sweep range (span); the zoom area applies only to the graphical display. (Compare the sweep settings in Figure 9-6: "Selecting the zoom area" and Figure 9-7: "Displaying the zoom area" above – they are identical.)

To optimize the graphical display in both axes, right-click in the diagram, and then click **Optimize**. Alternatively, you can reset the axes separately by using the **X-Axis** and **Y-Axis** commands.

X-Axis, Y-Axis

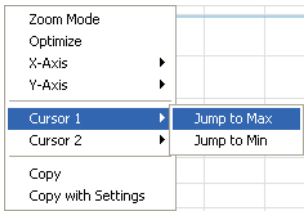
To optimize or reset an axis, right-click in the diagram, point to **X-Axis** or **Y-Axis**, and then click the respective command to optimize or to zoom out the selected axis.

Cursor 1, Cursor 2

By using the **Cursor 1** and **Cursor 2** commands, you can set the respective cursor to the minimum and the maximum of a curve as follows:

1. Right-click a curve in the diagram.
2. Point to **Cursor 1** or **Cursor 2**, and then click **Jump to Max** or **Jump to Min** to set the respective cursor to the maximum or the minimum of the curve.

Figure 9-8:
Setting the cursor 1 to the maximum



Hint: If both traces are close together and are displayed in one diagram, it might be difficult to select the curve you want to process. In this case, you can click **Always Two Diagrams**, select the trace in the respective diagram, and then set a cursor as described above. Then you can switch back to one-diagram display by clicking **Auto**.

Hint: To set the cursor to a specific frequency, you can enter this frequency directly in the frequency box next to the respective cursor.

Figure 9-9:
Setting the cursor 1 to a frequency

	Frequency	Trace 1		Trace 2	
☑ Cursor 1	10.700 MHz		-25.372 dB		-34.897 dB
☑ Cursor 2	11.241866 MHz		-88.824 dB		-25.482 dB
delta C2-C1	541.866 kHz		-63.452 dB		9.416 dB

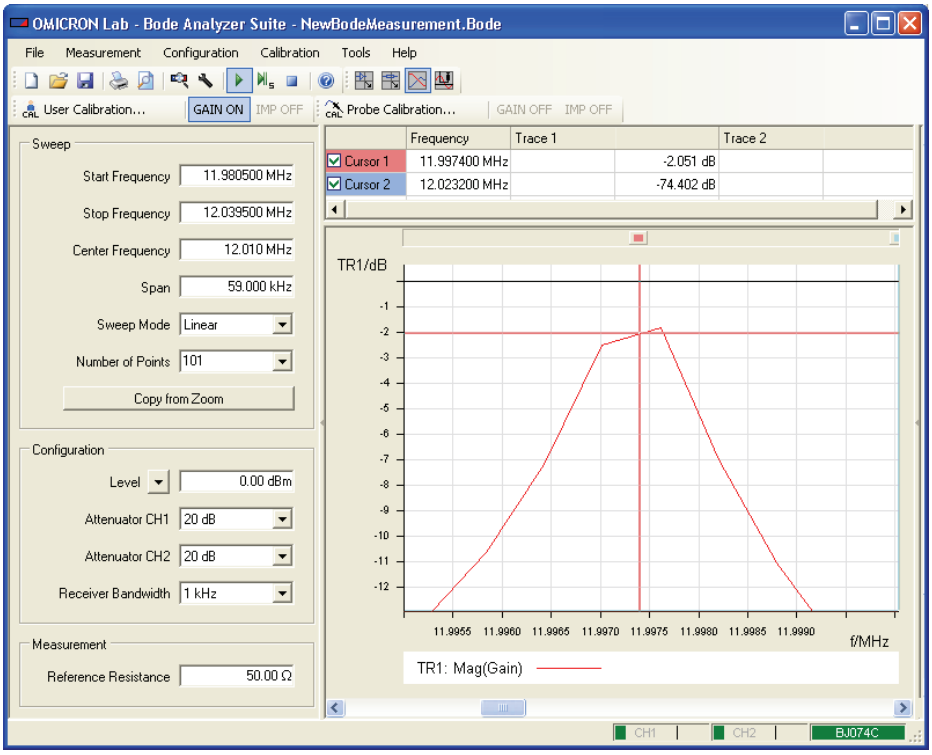
Copy from Zoom

By clicking the Copy from Zoom button you can copy the start and stop frequencies of the zoom area to the sweep settings, keeping the number of measurement points constant. This function is especially useful to measure a detail of a curve with a higher resolution.

Note: The **Copy from Zoom** command is available once the **Zoom Mode** has been activated.

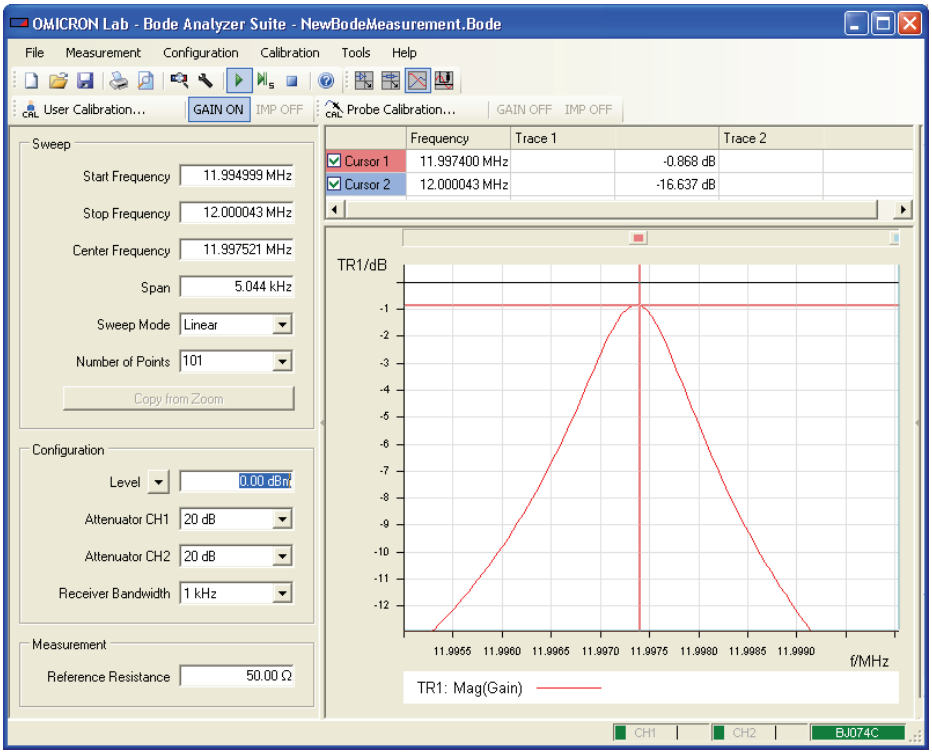
The following figure shows a zoom area of an measurement. Due to the low number of measurement points within the area, the displayed curve is not smooth.

Figure 9-10:
Measured curve with initial sweep settings



By applying the **Copy from Zoom** function the frequency span is narrower, resulting in a higher resolution of the measured curve.

Figure 9-11: Measured curve with sweep settings copied from the zoom area



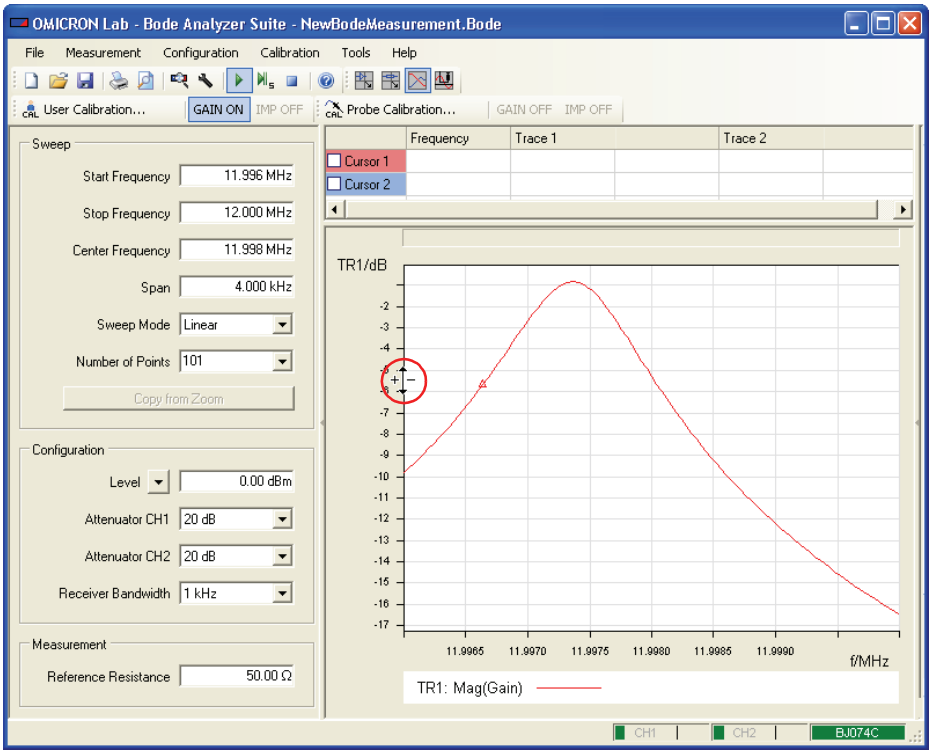
After using the **Copy from Zoom** function, the original sweep settings are lost. If used, the **User Calibration** is switched off, too.

Hint: Compare the frequency sweep settings before (see Figure 9-10: "Measured curve with initial sweep settings" on page 108) and after applying the **Copy from Zoom** function (see Figure 9-11: "Measured curve with sweep settings copied from the zoom area" above).

Special Zoom Function

In the **Zoom Mode**, when moving the pointer over an axis the pointer becomes a double-headed arrow. Then click the left mouse button to zoom in and the right mouse button to zoom out respectively.

Figure 9-12:
Special zoom function applied on Y-axis



Hint: This function is also available in the **Gain/Phase** mode and in the **Impedance/Reflection** mode.

Data and Memory

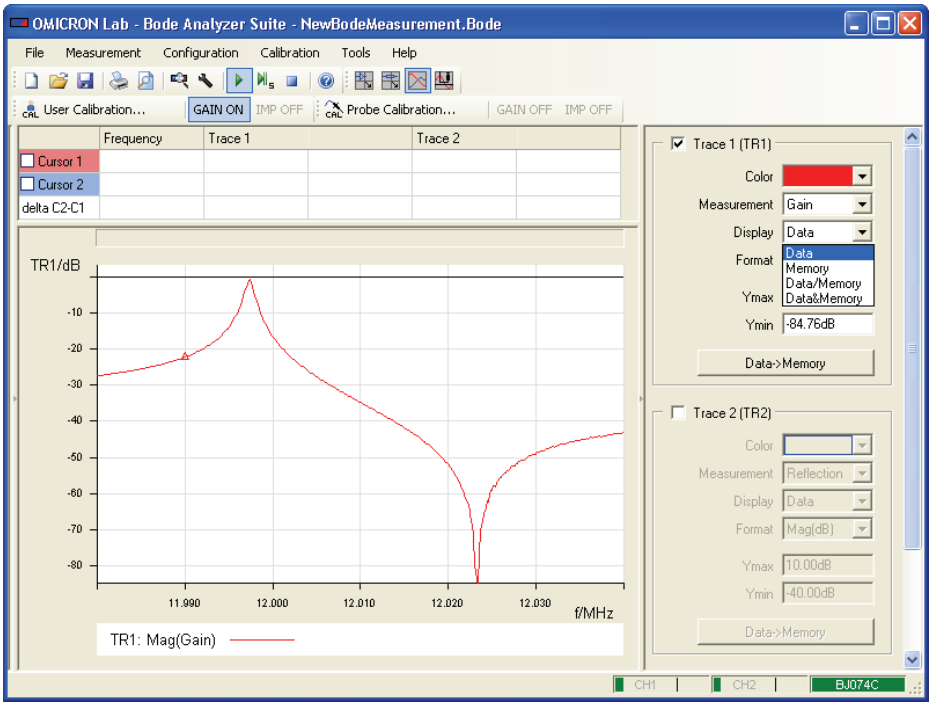
With the *Bode 100* you can copy the current measurement data into the trace memory and display it.

To store and display the measurement data:

1. Click the Data->Memory button to store the current measurement data into the trace memory.
2. In the **Display** list, select one of the following:
   - **Data** to display the current measurement data
   - **Memory** to display the stored measurement data
   - **Data/Memory** to display the difference between the current and the stored measurement data
   - **Data & Memory** to display the current and stored measurement data as two curves in the same diagram

   Hint: The **Data/Memory** option is particularly useful to compare two electrical components of the same type because even smallest differences in the frequency behavior can be detected easily.

Figure 9-13: Selecting **Display** function



Example: Using the data and memory functions

Example duration: 15 minutes

In this example you will learn step by step how to use the data and memory display function in the **Frequency Sweep** mode.

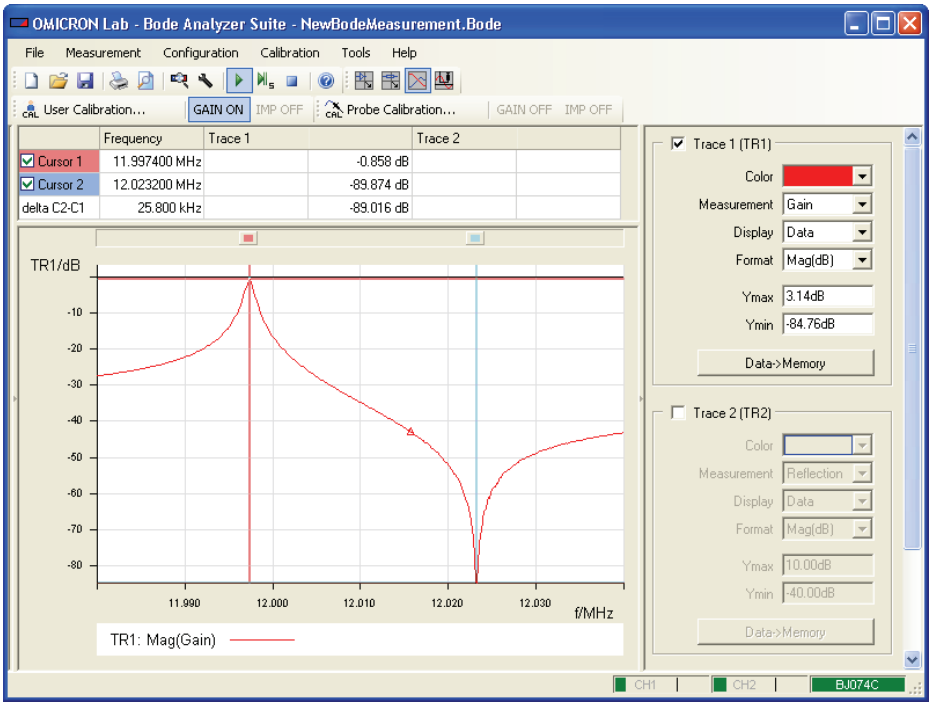
How to:

- Copy the current measurement data to the trace memory
- Compare the frequency responses
- Detect even smallest differences between the current and stored measurement data by using the **Data/Memory** display function

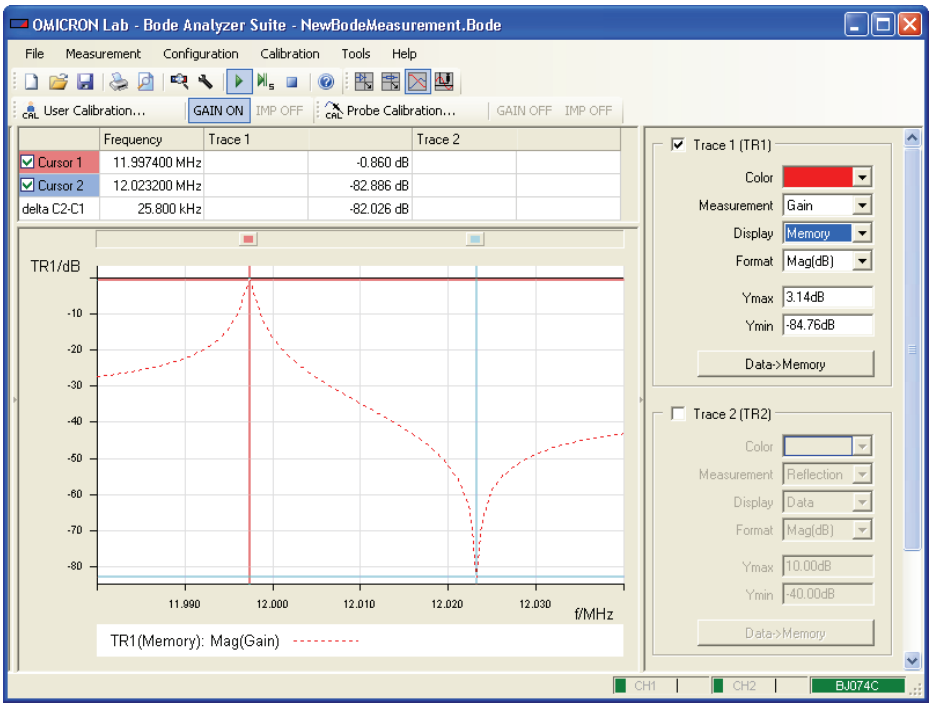
Question: How does touching the housing of the quartz filter on the sample PCB influence the measurement?

To find out the answer, proceed as follows:

1. Follow steps 1 to 14 of the example outlined in 5.1 "Example: Frequency Sweep Measurement" on page 46.
2. Clear the **Trace 2** check box.
   Your screen should now look like this:



3. Click the Data->Memory button to store the measurement data.
4. In the **Display** list, select **Memory**.
   The stored data is displayed as a dashed line.

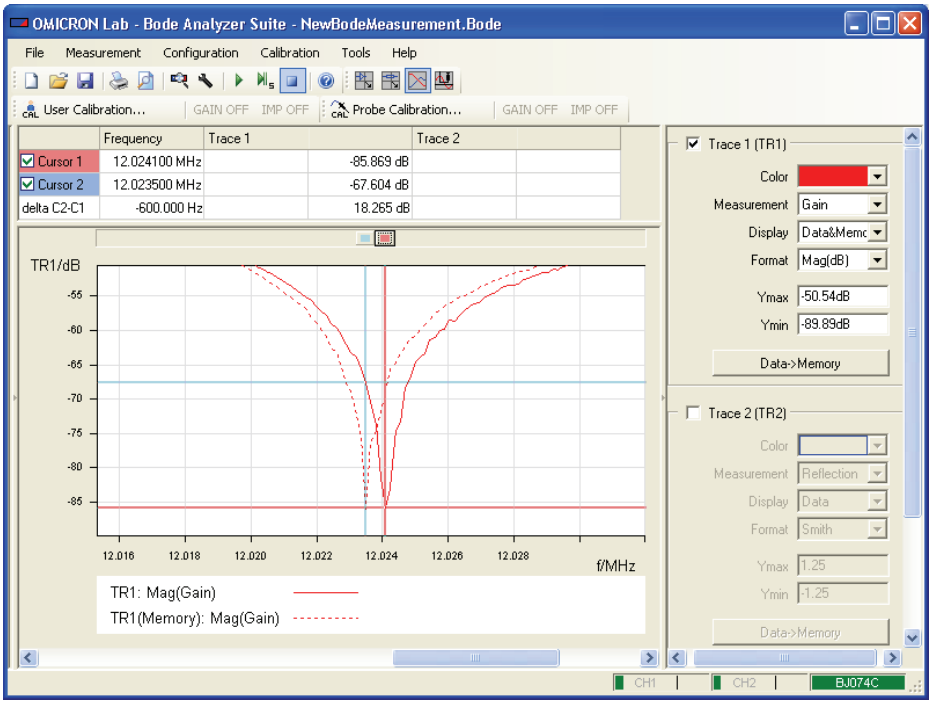


5. In the **Display** list, select **Data & Memory**, and then touch the housing of the quartz filter with your finger.
   By doing this you shift the parallel resonance frequency of the filter.
6. Mark the new parallel resonance frequency with the cursor 1 by using the **Jump to Min** function. Right-click the curve, point to **Cursor 1**, and then click **Jump to Min**.

Figure 9-14:
Setting the cursor 1 to the minimum

7. Now, you can measure the effect of touching the quartz filter by using the **delta C2-C1** function.

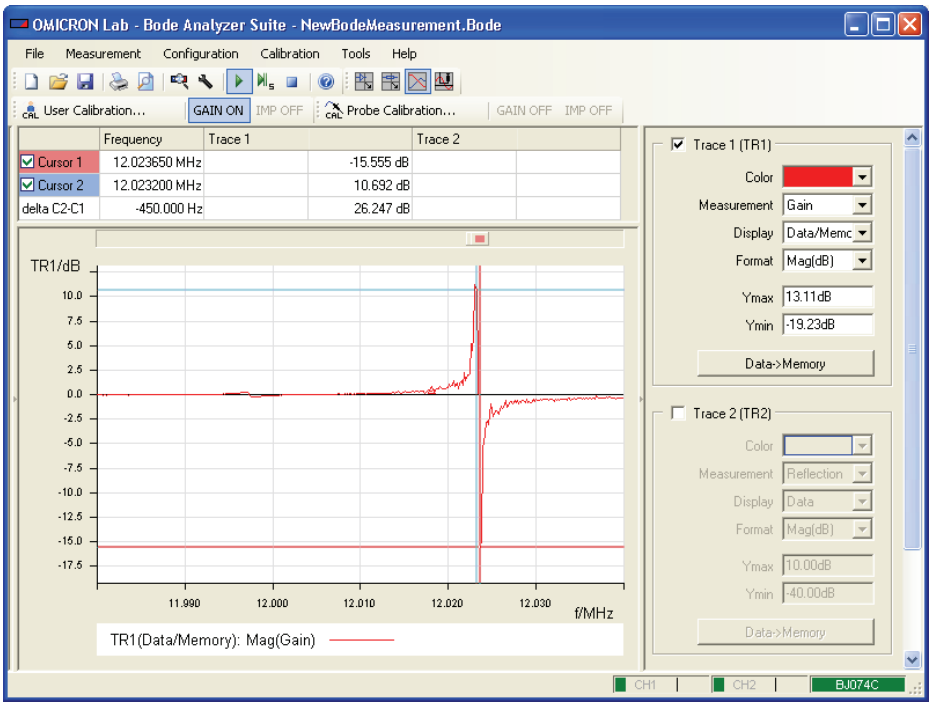
Hint: Use the **Zoom Mode** function to get a better view. The figure below shows a zoomed diagram showing the effect of touching the quartz filter's housing.



Result: Touching the quartz housing shifts the parallel resonance frequency by 450 Hz. You might measure different values with your quartz filter.

8. In the **Display** list, select **Data/Memory**, and then touch the filter.

9. Optimize the Y-axis.
   The diagram now displays the difference between the actual measurement data and the stored data.



If the curve is above the 0 dB line the current measured data is higher than the stored measurement data. If the curve is below the 0 dB line the currently measured data is lower than the stored measurement data.

Hint: The **Data/Memory** function allows you to detect even smallest differences between different parameters of the same component type (e.g. comparison of two quartz filters of the same type).

Congratulation! You learned how to use the data and memory functions in the **Frequency Sweep** mode.

How to:

- Copy the current measurement data to the trace memory
- Compare the frequency responses
- Detect even smallest differences between the current and stored measurement data by using the **Data/Memory** display function

9.2 Advanced Sweep Options

In the **Frequency Sweep** and **Frequency Sweep (External Coupler)** modes, you can choose between continuous sweep and single sweep measurements. In most applications, it is recommended to use the continuous sweep measurement since all measurement data is periodically updated.

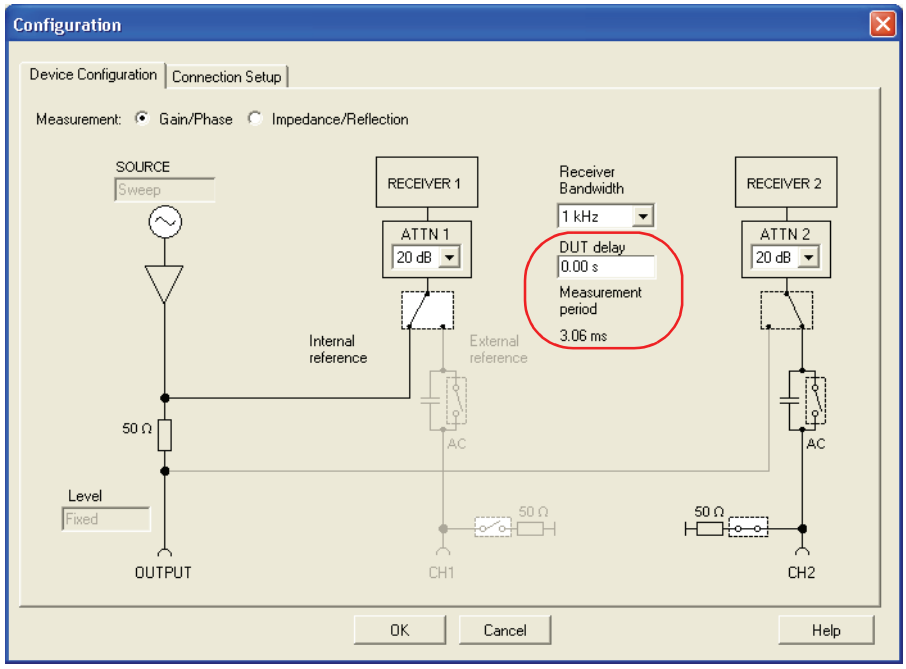
Single Sweep

You can use the single sweep measurement to capture one-time events or to produce a stable curve before using the **Copy** or **Copy with Settings** function.

DUT Delay, Measurement Period

In the **Configuration** window, you can find the **DUT delay** and **Measurement period** boxes.

Figure 9-15: **DUT delay** and **Measurement period** fields



The measurement period indicates the time the *Bode 100* requires to perform measurement at one frequency point. By multiplying this value with the selected number of measurement points you can get an estimate of the expected sweep time.

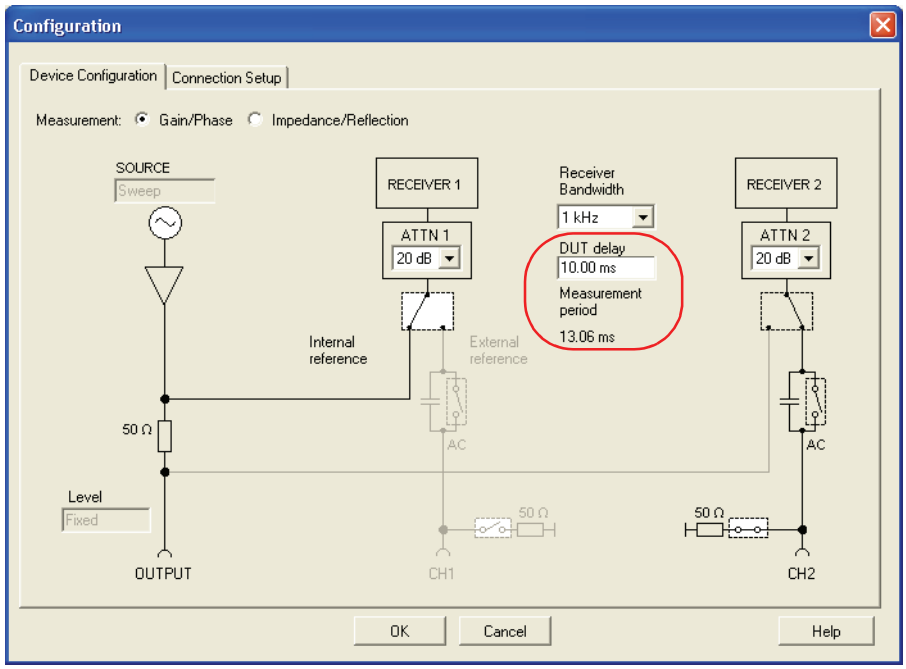
Example: Expected sweep time for 401 points and a measurement period of 3.06 ms

sweep time = 3.06 ms • 401 frequency points = 1.2 s

Some devices under test require a settling time when the input frequency has been changed (e.g. phase-locked loops). The DUT delay allows setting this waiting time.

Let's assume our DUT requires a 10 ms settling time each time the input frequency has changed. To allow for this waiting time, enter 10 ms in the DUT delay box.

Figure 9-16:
Setting the DUT delay



The measurement period is automatically updated. When using the same number of measurement points as before, the sweep time is now much longer.

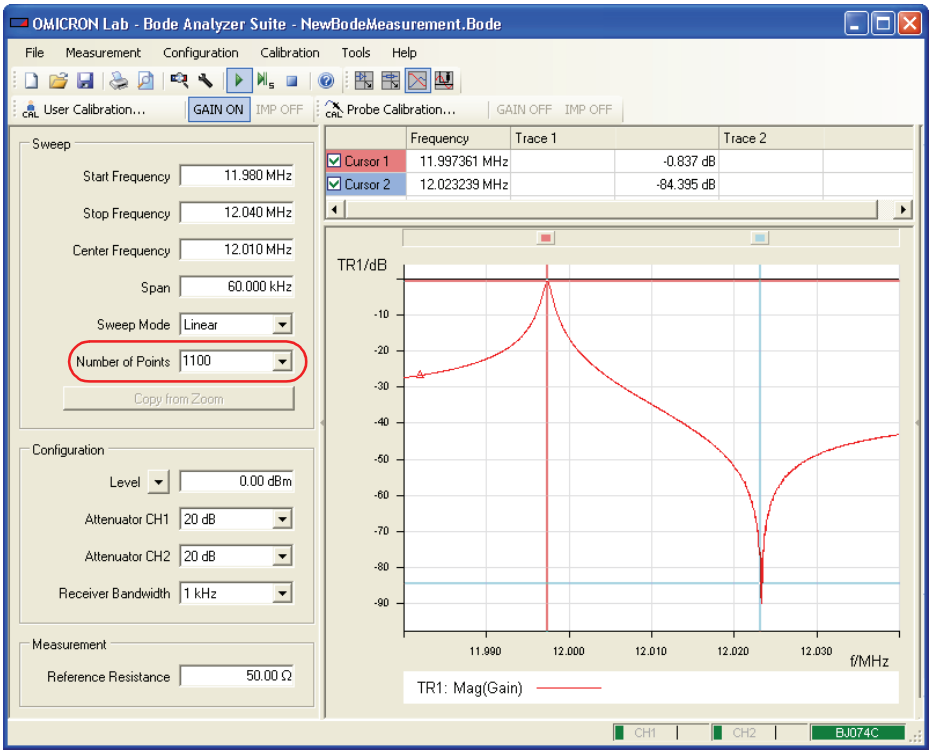
sweep time = 13.06 ms • 401 frequency points = 5.23 s

Hint: Set the DUT's delay to zero after your measurement is completed to ensure the shortest sweep time possible for next measurements.

Number of Measurement Points

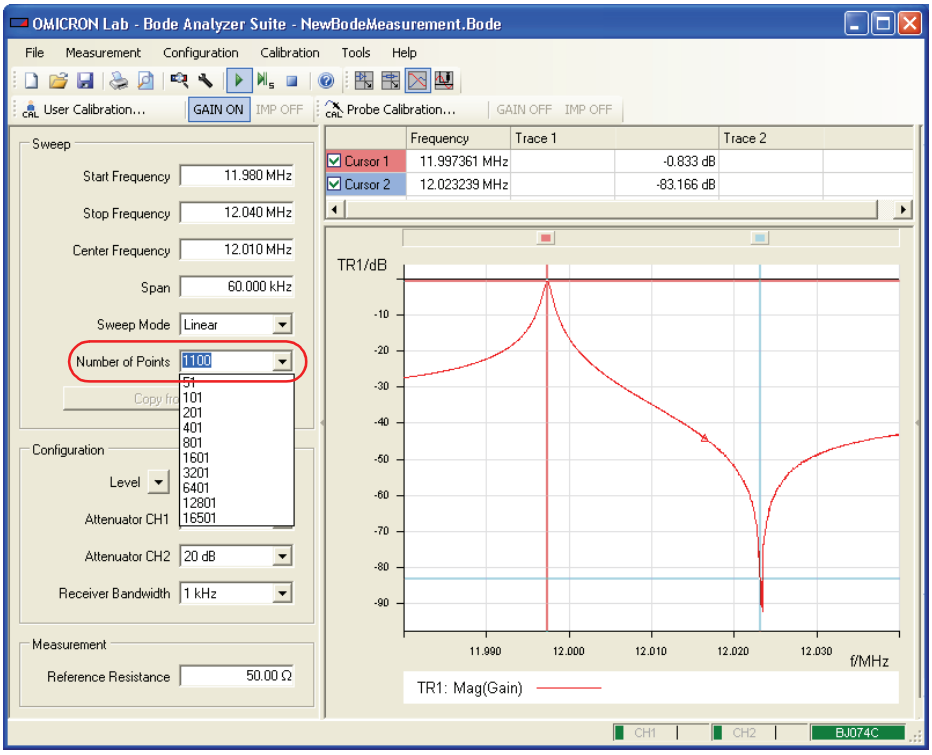
Sometimes a very specific number of measurement points is required. With the *Bode 100* you can set any number of measurement points in the range 10…16501. To set the number of measurement points, click in the **Number of Points** box, and then enter the number of points you wish to use for your measurement.

Figure 9-17:
Entering the number of measurement points



To get back a predefined number of measurement points, select the corresponding entry in the **Number of Points** list.

Figure 9-18:
Selecting a predefined number of measurement points



9.3 Level Shaping

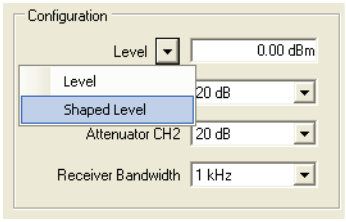
By using the **Shaped Level** function available in the **Frequency Sweep** and **Frequency Sweep (External Coupler)** modes you can vary the *Bode 100* output level within the frequency sweep range. Possible applications for this functionality include:

- Avoiding nonlinearities during Control Circle analysis (e.g. of DC/DC converters)
- Reduction of noise or avoiding overloads for circuits showing a high dynamic variation of gain within the frequency sweep range

To activate the **Shaped Level** function:

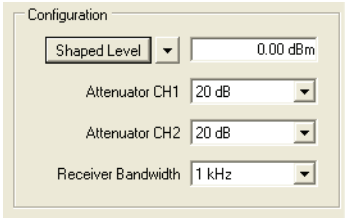
1. In the **Configuration** area, click the **Level** arrow, and then click **Shaped Level**.

Figure 9-19:
Select the
Shaped Level function



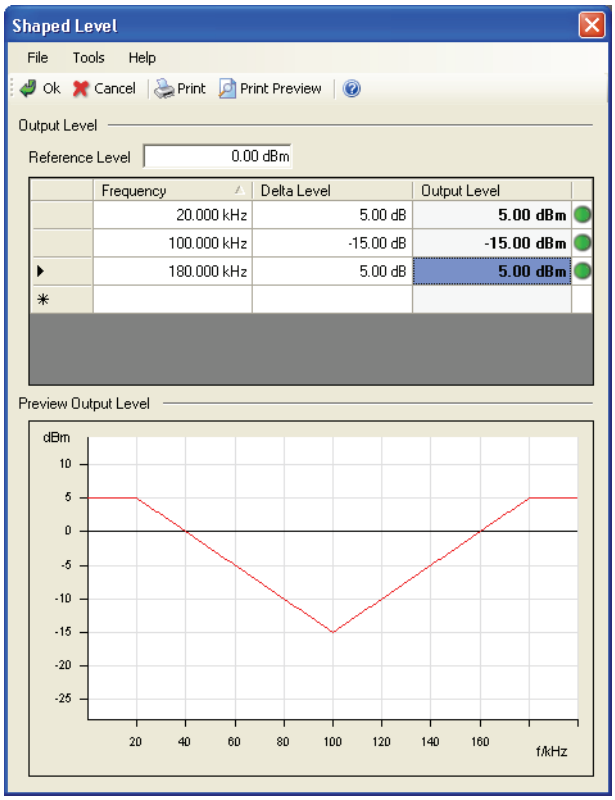
2. Click the **Shaped Level** button.

Figure 9-20:
Open the
Shaped Level window



In the **Shaped Level** window, enter the frequencies and the delta output levels in dB relative to the reference level. In the **Output Level** column, the calculated output levels are displayed.

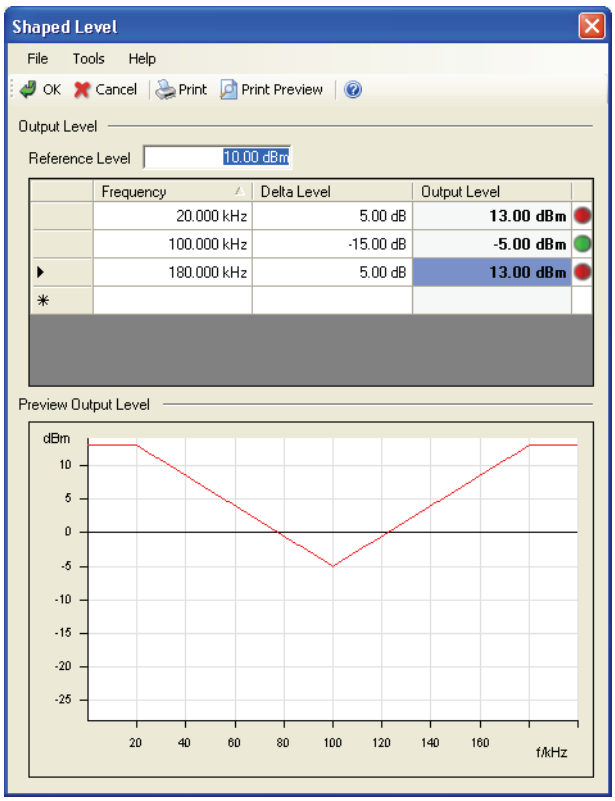
Figure 9-21:
Enter frequencies and delta levels



The green indicators next to the **Output Level** column signal that the output level is within the *Bode 100* output level range (–27 dBm…13 dBm). If an entered delta level results in an output level outside the *Bode 100* range, the output level is limited accordingly. The output level limiting is signaled by a red indicator (see the following figure).

You can shift the output level frequency characteristic up or down by changing the reference level in the **Reference Level** box.

Figure 9-22:
Change reference level

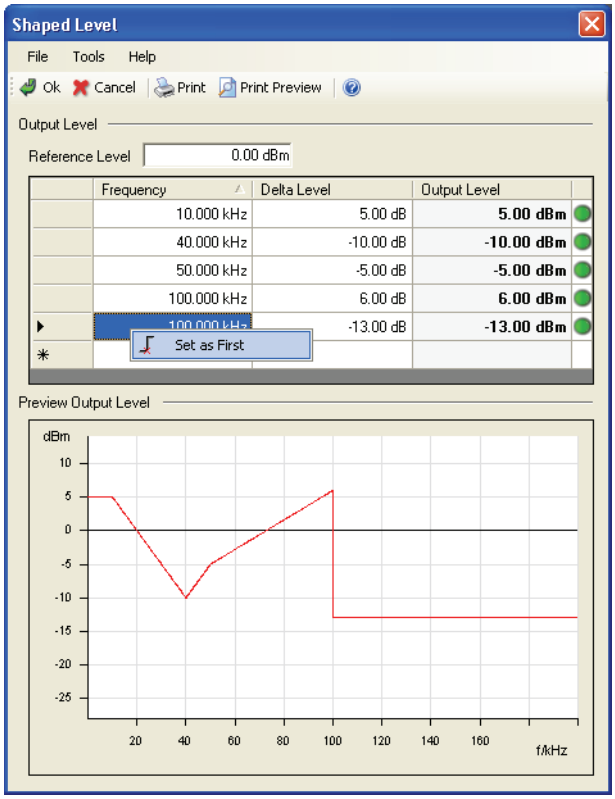


Hint: Based on the entered delta level the calculated output levels at 20 kHz and 180 kHz are outside the level range of the *Bode 100*. Therefore the values are limited to the maximum possible output level and the red indicators are activated.

You can shape very steep slopes by entering two delta levels at the same frequency. To select either the rising or falling edge, adjust the sequence of the delta levels:

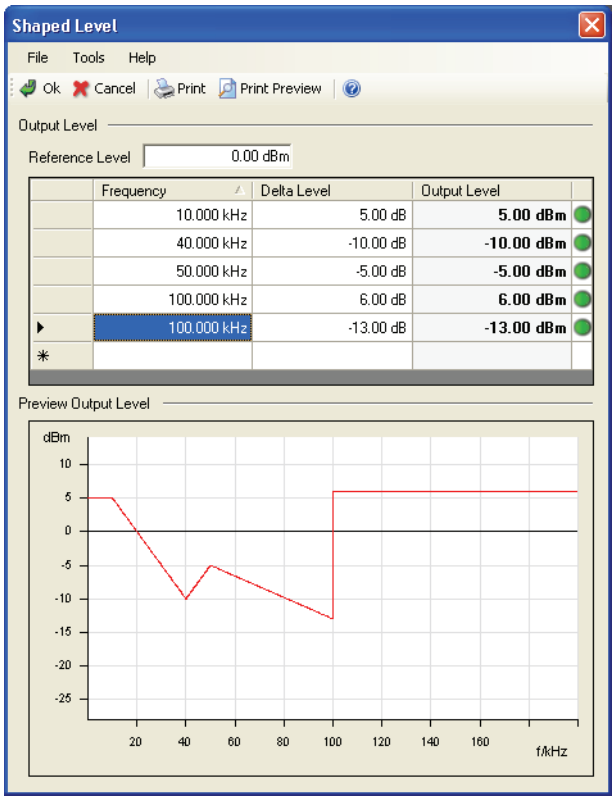
1. Click in the respective frequency cell.
2. Right-click in the selected frequency cell, and then click **Set as First** or **Set as Second**.

Figure 9-23:
Original characteristic



The figure shows the output level frequency characteristic before clicking **Set as First**.

Figure 9-24:
Characteristic with changed slope

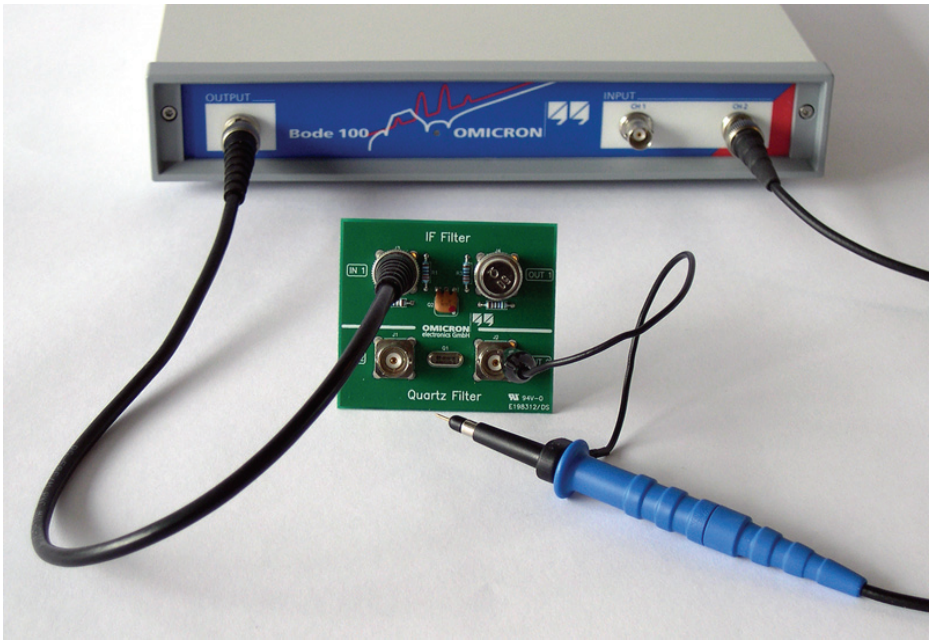


The figure shows the output level frequency characteristic after clicking **Set as First**.

9.4 Using Probes

With the *Bode 100* you can use measurement probes for input channel 1 and input channel 2.

Figure 9-25:
Using a probe



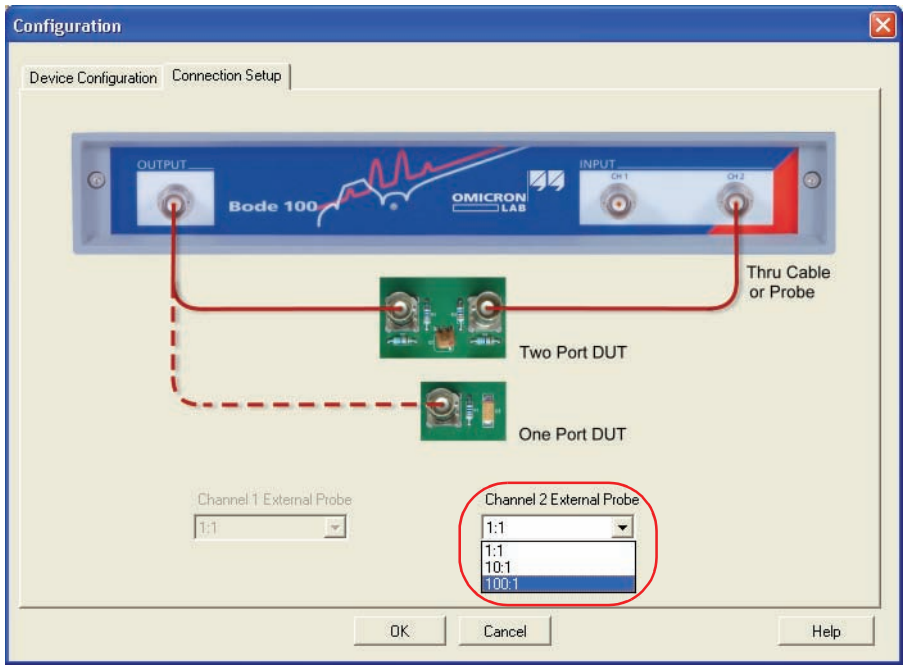
Using the probes is recommended in the following applications:

- Measurements at points within the DUT circuitry not accessible with BNC cables
- Measurements of devices under test which are sensitive to capacitive or resistive influences (e.g. resonant circuits)

When using a probe, consider the following instructions:

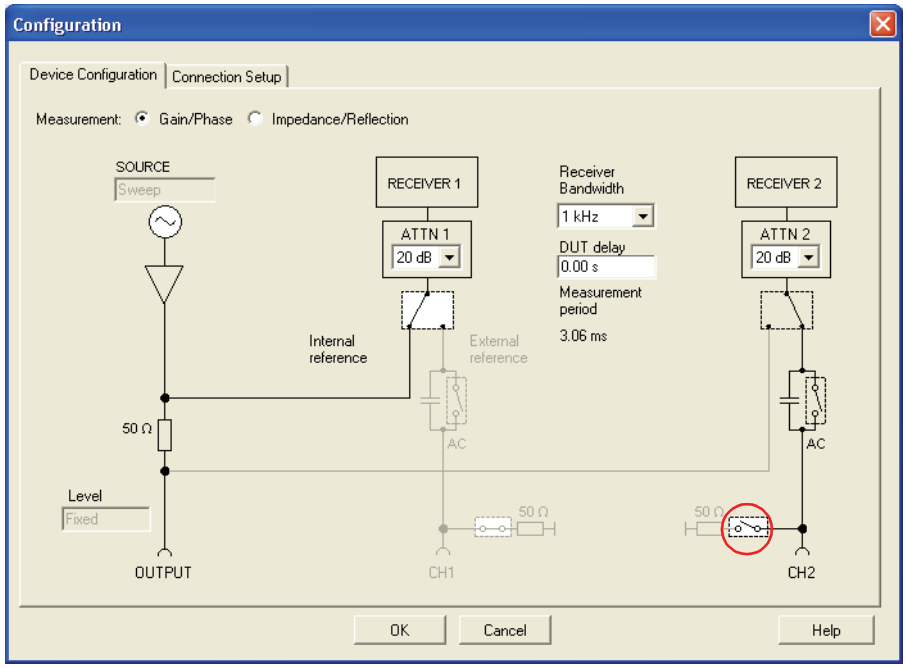
1. Always set the correct probe ratio in the **Connection Setup** tab of the **Configuration** window.
   You can choose between 1:1, 10:1 or 100:1.

Figure 9-26:
Setting the probe ratio



2. For correct probe operation switch the input impedance of the channel connected to the probe to high impedance (1 MΩ).

Figure 9-27:
Setting high input impedance of channel 2

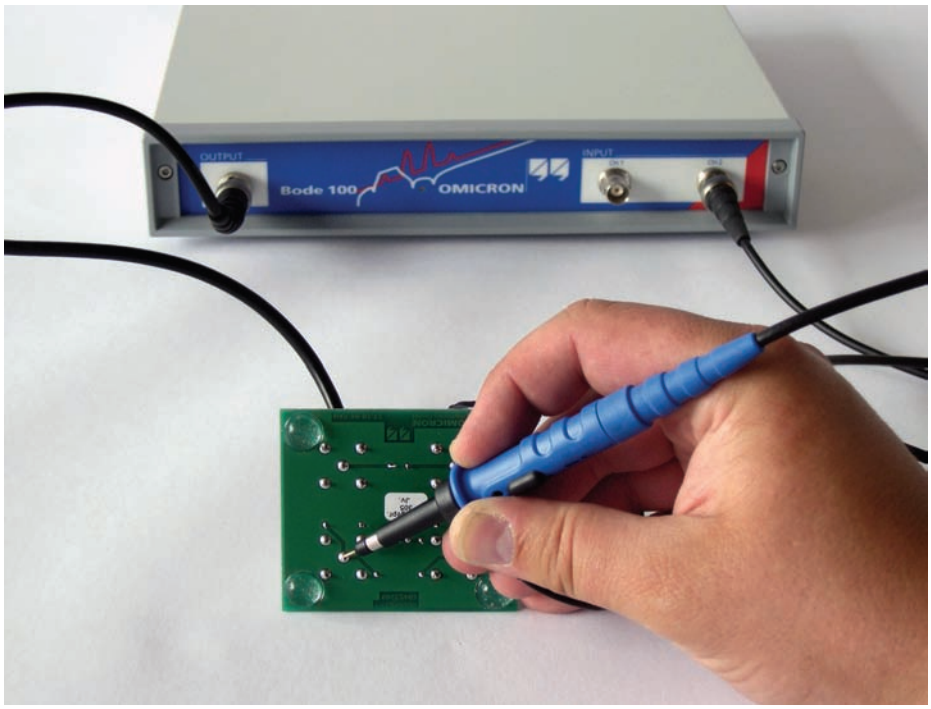


3. Ensure that your DUT is terminated correctly.

   Hint: When using a probe with a DUT which requires a 50 Ω termination, you can simply connect the BNC 50 Ω load delivered with your *Bode 100* to the output of the DUT.

4. To obtain accurate measurement results, calibrate the *Bode 100* as follows:
5. Connect the ground of the probe with the ground of the DUT and touch the DUT's input with the probe tip.
6. Now, perform the calibration in the **Gain/Phase** mode as described in 3.3 "Example: Gain/Phase Measurement" on page 24.

Figure 9-28:
Touching the DUT's input with the probe's tip



Hint: Ensure that the probe's tip is in contact with the DUT's input all the time until the calibration is finished.

7. After having calibrated the probe, start your measurement at any point of the DUT using the probe.

The first time I used my measurement **probe** to **zoom** into an electrical circuit will always remain in my **memory**.

Congratulation! You learned how to use the advanced functions of the *Bode 100*.

How to:

- Use the advanced display functions like **Zoom** and **Copy to Clipboard**
- Use the advanced sweep options
- Use the level shaping functionality
- Use probes

10 Automation Interface

So far you have worked with the *Bode 100* by using the graphical user interface (GUI) of the *Bode Analyzer Suite*. Beside this very comfortable user interface for laboratory use, the *Bode 100* provides also an all-purpose application programming interface (API) for interfacing with the *Bode 100*.

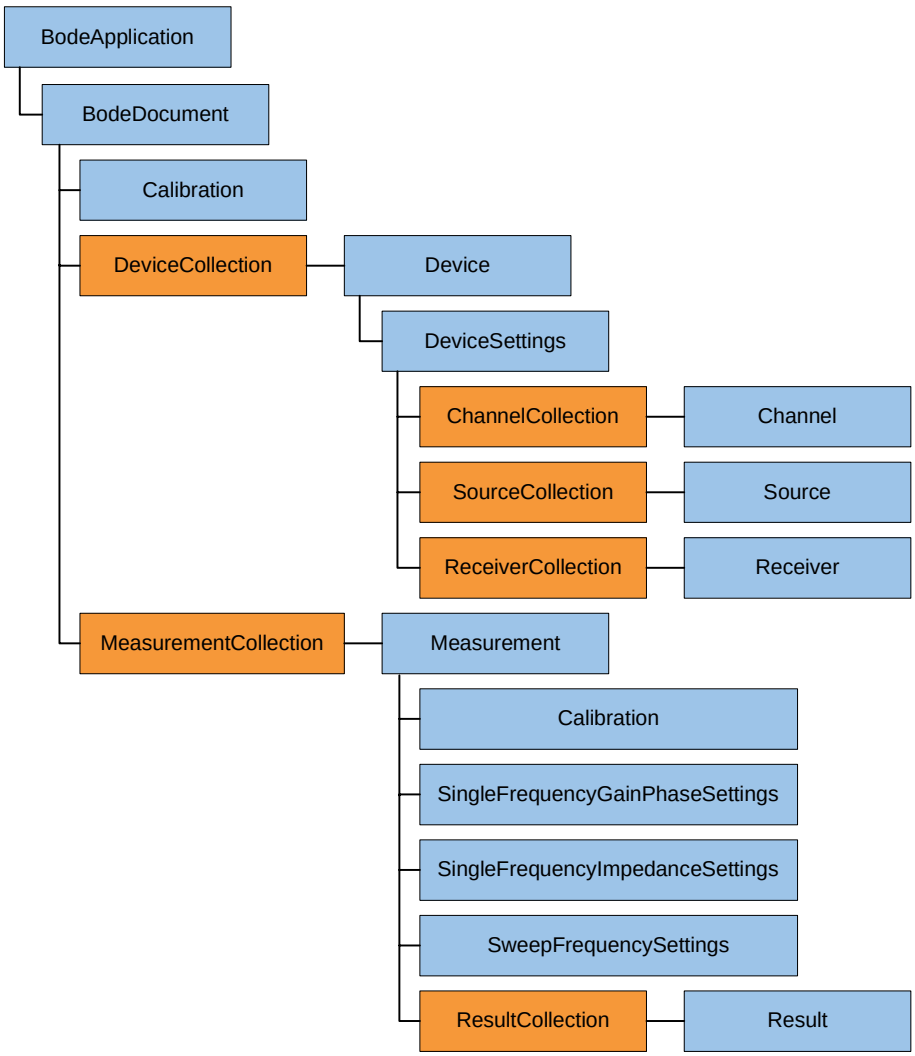
The *Bode Analyzer Automation Interface* supports OLE automation and allows quick access of the *Bode 100* using OLE compatible controllers such as Excel® or programming languages like Visual C++®. This allows simple integration of the *Bode 100* into automated measurement setups. Additionally, by using the *Bode Analyzer Automation Interface* you can directly control the *Bode 100* with programs such as LabVIEW and MATLAB.

The *Bode Analyzer Automation Interface* is automatically installed during the *Bode Analyzer Suite* installation and is available for use as soon as a *Bode 100* unit is connected to your computer. (You do not need to start the *Bode Analyzer Suite* to access the *Bode Analyzer Automation Interface*).

Figure 10-1: "Object hierarchy overview" on page 130 shows an overview of the command structure for the *Bode Analyzer Automation Interface*.

Note: An overview on the measurement functions available through the *Bode Analyzer Automation Interface* is provided in the Automation Interface Object Hierarchy and in the Automation Interface Reference. Both documents are located in the Automation subdirectory in the Bode Analyzer Suite directory. You can find detailed information how to access this directory on page 131.

Figure 10-1:
Object hierarchy overview



Hint: You can find a detailed overview of the *Bode Analyzer Automation Interface* object hierarchy in the Automation subdirectory of the Bode Analyzer Suite directory.

Figure 10-2: "Example of code segment for accessing the Bode Analyzer Automation Interface" on page 131 shows a typical code segment used to access functions of the *Bode Analyzer Automation Interface*. In this example, a *Bode 100* unit is searched for and, after a device has been found, measurement parameters are set.

Figure 10-2: Example of code segment for accessing the *Bode Analyzer Automation Interface*

Example

Visual Basic

```
Public Sub Main()
    Dim myBodeApp As New BodeAnalyzer.BodeApplication
    Dim myDocument As BodeAnalyzer.BodeDocument
    Dim mySelectedDevice As BodeAnalyzer.Device

    Set myDocument = myBodeApp.Document
    myDocument.Devices.ScanForDevices

    If myDocument.Devices.Count > 0 Then
        ' select the first device
        myDocument.Devices(1).SelectAndInit
        ' set default device settings
        myDocument.SelectedDevice.DeviceSetup.Bandwidth = Bandwidth_Hz100
        myDocument.SelectedDevice.DeviceSetup.DUTDelay = 0.000012 ' 12 µs
        myDocument.SelectedDevice.DeviceSetup.Channels(2).Termination50Ohm = True
        myDocument.SelectedDevice.DeviceSetup.Channels(2).Probe = ExternalProbe_Probe10to1
        myDocument.SelectedDevice.DeviceSetup.Receivers(1).Attenuator = Attenuator_dB0
        myDocument.SelectedDevice.DeviceSetup.Receivers(2).Attenuator = Attenuator_dB10
        myDocument.SelectedDevice.DeviceSetup.Sources.Level = 20 ' 20 dBm aren't possible, is changed to 13dBm (max. Level)
        myDocument.SelectedDevice.DeviceSetup.Sources(1).On = True
        myDocument.SelectedDevice.DeviceSetup.Sources(2).On = False


        Set mySelectedDevice = myDocument.SelectedDevice
        MsgBox "Device (Id: " & mySelectedDevice.DeviceId & " , Serial: "
               & mySelectedDevice.SerialNumber & ") selected and ready to use."
    Else
       ' No device connected
        MsgBox "No device connected."
        End
    End If

    myBodeApp.Quit
End Sub
```

See Also

Device Members

For a complete description of the *Bode Analyzer Automation Interface*, see the Bode Analyzer Automation Interface Reference. To access it:

1. On the taskbar, click the **Start** button, and then point to **Programs**.
2. Point to **Bode Analyzer Suite**, point to **Automation**, and then click **Automation Interface Reference**.

Shout "OLE" to celebrate your new knowledge about the *Bode Analyzer Automation Interface*.

Congratulation! You learned:

- Basics of the *Bode Analyzer Automation Interface*
- About the object hierarchy of the used command structure
- Where to look for further information on the *Bode Analyzer Automation Interface*

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11 Troubleshooting

11.1 USB Cable and/or Power Supply to the *Bode 100* Is Missing

If the serial number field in the status bar displays **No Device** on red background then the *Bode Analyzer Suite* does not communicate with the *Bode 100*.

Solution: Connect the USB cable to the computer and the *Bode 100* and check the power supply. Then click the **Search and Reconnect Device** toolbar button to connect the *Bode 100* with the computer.

11.2 Lost Communication

The loss of the power supply and other events can cause loss of communication between the *Bode 100* and the computer. In this case, the serial number field in the status bar displays **No Device** on red background.

Solution: Click the **Search and Reconnect Device** toolbar button to connect the *Bode 100* with the computer.

11.3 Cannot Select Frequencies Lower Than 10 Hz

To activate the extended frequency range of 1 Hz…40 MHz, click **Options** on the **Tools** menu, click the **Measurement** tab, and then select the **Measurement Range 1 Hz - 40 MHz** option (see 8.2 "Setting the Measurement Range" on page 98).

Note: The activation of the measurement range of 1 Hz…40 MHz will increase calibration times including the internal calibration performed at the startup and each time you reconnect to the *Bode 100*.

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12 Technical Data

12.1 *Bode 100* Specifications

Table 12-1:
Bode 100 specifications

Characteristic	Rating
Frequency range (selectable by the *Bode Analyzer Suite*)	10 Hz…40 MHz or 1 Hz…40 MHz (extended frequency range)
OUTPUT connector	
Output impedance	50 Ω
Connector	BNC
Wave form	Sinusoidal signal
Output voltage	0.01…1 Vrms into 50 Ω load –27 dBm…13 dBm
CH 1 INPUT, CH 2 INPUT connectors	
Input impedance	Low or high impedance selectable
Low impedance	Input impedance 50 Ω
High impedance	Input impedance 1 MΩ ±2% Input capacitance 40…55 pF
Connectors	BNC
Receiver bandwidth	1 Hz, 3 Hz, 10 Hz, 30 Hz, 100 Hz, 300 Hz, 1 kHz, 3 kHz
Input attenuator	0 dB, 10 dB, 20 dB, 30 dB, 40 dB
Input sensitivity	100 mV full scale for input attenuator 0 dB
Dynamic range	> 100 dB at 10 Hz receiver bandwidth
Gain error	< 0.1 dB (calibrated)
Phase error	< 0.5º (calibrated)
USB interface	
Connector	Type B

12.2 Power Requirements

Table 12-2:
Power requirements

Characteristic	Rating
AC power adapter	
Input voltage/frequency	100…240 V / 47…63 Hz
DC power supply	
Output voltage/output power	+10…24 V / 10 W
Inner connector	+10…24 V
Outer connector	Ground
Inner diameter	2.5 mm
Outer diameter	5.0 mm

12.3 Absolute Maximum Ratings

Table 12-3:
Absolute maximum ratings

Characteristic	Absolute Maximum Rating
DC power input	
DC supply voltage	+28 V
DC supply reverse voltage (device does not work)	–28 V
CH 1 INPUT, CH 2 INPUT connectors (high impedance)	
Maximum AC input signal	50 Vrms for 1 Hz…1 MHz 30 Vrms for 1 MHz…2 MHz 15 Vrms for 2 MHz…5 MHz 10 Vrms for 5 MHz…10 MHz 7 Vrms for 10 MHz…40 MHz
Maximum DC input signal	50 V
CH 1 INPUT, CH 2 INPUT connectors (low impedance)	
Maximum input power	1 W (= 7 Vrms)
OUTPUT connector	
Maximum reverse power	0.5 W

12.4 Computer Requirements

Table 12-4: Computer requirements

Characteristic	Requirement
Minimum configuration	Pentium 500 MHz, 256 MB RAM, CD-ROM drive
Recommended configuration	Pentium 1 GHz, 256 MB RAM, CD-ROM drive
Interface	USB 1.1 or USB 2.0
Operating system	Windows® 2000, Windows® XP, Windows® XP 64-bit, Windows® Vista, Windows® Vista 64-bit

12.5 Environmental Requirements

Table 12-5: Environmental requirements

Characteristic	Condition	Rating
Temperature	Storage	–35…+60ºC / –31…+140ºF
	Operating	+5…+40ºC / +41…+104ºF
	For specifications	23ºC ± 5ºC / 73ºF ± 18ºF
Relative humidity	Storage	20…90%, non-condensing
	Operating	20…80%, non-condensing

12.6 Mechanical Data

Table 12-6: Mechanical data

Characteristic	Rating
Dimensions (w × h × d)	26 × 5 × 26.5 cm / 10.25" × 2" × 10.5"
Weight	< 2 kg / 4.4 lbs

Hint: You can find more technical data on the OMICRON Lab Web site www.omicron-lab.com.

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Contact Information / Technical Support

E-Mail: support@omicron-lab.com

Web: www.omicron-lab.com

or contact the following OMICRON electronics customer service centers:

Europe, Africa, Middle East

OMICRON electronics GmbH, Klaus, Austria

Phone: +43 5523 507-333

Fax: +43 5523 507-999

Asia, Pacific

OMICRON electronics Asia Ltd, Hong Kong

Phone: +852 2634 0377

Fax: +852 2634 0390

North and South America

OMICRON electronics Corp. USA, Houston, Texas

Phone: +1 713 830-4660 or *1 800 OMICRON*

Fax: +1 713 830 4661

Alternatively, visit our Web site www.omicron-lab.com for customer service centers in your area.

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